1962

Optimum resource allocation on farms in the Argentina cornbelt

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OPTIMUM RESOURCE ALLOCATION
ON FARMS IN THE ARGENTINA CORNBELT

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by

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A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
MASTER OF SCIENCE

Major Subject: Agricultural Economics

Signatures have been redacted for privacy

Iowa State University
Of Science and Technology
Ames, Iowa

1962

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INTRODUCTION

The Argentinian economy is dependent to a considerable extent on income from agriculture. Wheat, corn and beef cattle have always been the most important agricultural products. Argentina's fertile land is especially suitable for these crops with temperate climate and the flat cattle terrain providing a unique natural advantage. The bulk of agricultural production is carried out in the central Pampa area, a treeless plain with deep, rich soils and rainfall of about 32-35 inches per year. Located within this area is the rich Argentine corn belt, lying north of the Province of Buenos Aires and including the southern extremity of the Province of Santa Fé.

However, in spite of these natural advantages, the prevailing income per farm in this area is not favorable. In general, prevailing price-cost relationships have made it more and more difficult for the farmer to obtain reasonable returns to labor, investment and management. Effects are singularly marked in the corn belt because of high specialization in corn production for export with the parallel decline or stabilization of external prices. In contrast, the continuous increase of some input prices, such as machinery, most of which is imported, has increased farm production costs.

A low level of technology, maladjustment of resources, problems in connection with tenure systems, and unstable agricultural policies have also influenced the equilibrium between the products and factors of production. The cost of productive factors has increased faster than have prices received by farmers, resulting in smaller profits.

A farm survey was conducted in 1959 so as to define more specifically some of the important problems affecting agricultural production. Two different localities were chosen in Pergamino, one of the most important crop-producing counties in the Province of Buenos Aires as well as in the corn belt. Pergamino ranks first among the counties producing corn and also is one of the leaders in producing wheat and sunflower seed. Other cash crops are limited to small acreages. The natural favorable conditions for production of forages for grazing make livestock raising also prominent.

The main difference between the two localities studied in the survey was the size of farms operated. A preliminary analysis of the survey showed an apparent underemployment of the labor supply.

How can farm income in Pergamino be improved? What adjustment in resource use, especially labor, should be made? How much would an increase in the quantity of resources, especially capital, add to total production? What will the economic effects of growing more grain, or more forage crops, and breeding more intensive livestock enterprises be? How can improved cropping and livestock systems use more of the underemployed labor, thus increasing returns? Answers are sought for these questions.

Surely, one method for increasing the labor productivity where capital and land are limited would be to reallocate part of the labor to non-farm activities. Job prospects seem to be favorable in Argentina and its economy is rapidly shifting to more industrialization. Consequently, movement of labor from farms could be possible in the near future. However, this study concentrates on short run adjustments at the farm level, rather than broader adjustments at the national level.

Another way to absorb the apparent excess of labor supply would be to increase land per farm. However, in the aggregate, land supplies are relatively fixed, so any general increase in farm size would require transfer of labor out of agriculture.

Furthermore, the inflexibility of the present tenure system does not allow wide changes in land holding. Any proposed solution in opposition to this system would be unrealistic at the present time because it is almost impossible to vary farm size by renting or acquiring more land. However, a plan assuming non-limiting land and non-limiting capital was developed in this study but only as a general indicator of the most efficient farm size for absorbing the current labor supply.

The alternatives which seem most reasonable are those which would allow farmers to make fuller use of the labor supply already on the farm.

OBJECTIVES OF THE STUDY

The primary objectives of this study are:

1. to analyze the combination of crops and livestock activities which will maximize farm income with capital fixed at the present levels of operation and with capital varying at different levels, given the present pattern of farm size.

2. to determine at what level of capital the labor supply limits production or how much of this labor still remains unused after the land resource has limited the production process.

3. to compare how beef cattle, and hog and poultry enterprises affect the labor utilization and maximization of profits, given the size of farm.

4. to determine, under the assumption of non-limiting capital level, the size of farm (amount of land) and the combination of enterprises, including and excluding hogs, which will absorb to the maximum the available labor supply.

A more general objective of the study is to examine techniques and principles which may make a contribution to farming efficiency when applied in Argentina. Linear programming will be applied for the first time to farm organization problems in this country with the expectation that the study will provide hypotheses for further and more detailed research dealing with the organization of farms in Argentina.

Assumptions

The following assumptions were made in working out the different situations and plans:

Effect upon economic conditions

If the farm production of the area increases as a consequence of improved farm organization, the increase will not affect farm price relationships and market opportunities.

Soil and other physical characteristics

The area analyzed has fairly homogeneous soil types and other physical characteristics. Consequently, yields are considered similar for different farms. However, the crops and livestock combinations may vary from one farm size to another.

It is also assumed that the soil and physical characteristics allow most farmers to introduce the changes suggested by the solutions of the different situations.

Prices

Commodity prices are assumed constant at the 1960 price level.

Plans

The optimum plan is the one resulting in the highest money income as long as it does not basically change the structure of the family operated farm. Other farmer objectives, like leisure or freedom from risk, were excluded from the study.

These assumptions will be realistic for most of the farmers in the small area considered. Subsequently, plans suggested will apply to all farms in the region with characteristics similar to those farms analyzed in this study.

SOURCE OF INFORMATION

Partial data for this study were obtained from a farm survey carried out in Pergamino* by Instituto Nacional de Tecnología Agropecuaria in 1959. The objective of the survey was to find out which was (a) the most common farm organization and (b) how farms with the highest returns in the region were organized.

The population was divided in three size groups, according to the number of acres in cultivation and their relative importance and contribution to the total agricultural production of the county.

Small-size farms, having less than 62 acres in cultivation, accounted for 24% of the total number of farms; but only 3% of the total acreage in cultivation.

Medium-size farms, between 62 and 360 acres, had 65% of the total number of farms and represented 48% of the total acreage in cultivation.

Farms larger than 360 acres had the same percentage of the total acreage but represented only about 10% of the total population.

A sample of 50 farms was obtained from the medium size

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*The survey which provided some of the data for this study was conducted under the supervision of Dr. Walter Schaeffer, F.A.O. specialist.

group. Most of the basic information utilized in planning the study, that is typical sizes, units of labor available, present level of working capital, yields, and so forth, was drawn from this group. However, the survey was not designed to provide input-output coefficients for labor, machinery, power, fuel, seed, and so forth, used in producing crops and livestock enterprises.

Since input-output coefficients are fundamental in the application of linear programming, another study was used to provide these estimates (8). This source provided in detail the direct labor employed in corn, wheat and oat crops, tractor size and hours used for the most common operations, size of other machines and hours used, and fuel and oil consumed in performing the different farm operations. Most of these data apply to areas with soils, rainfall and temperature similar to those of Pergamino. Nevertheless, input-output coefficients were related and compared to information from different sources and adjusted accordingly. In other cases, where it was impossible to obtain direct information related to the area under study, data has been adapted from USA sources. For example, most of the input-output coefficients for beef cattle feeding were obtained from Oklahoma State University (2). In Oklahoma the beef production system is quite similar to that in Argentina's Pampa. For hogs and poultry, coefficients were adapted from data published by Iowa State University (1) and the University of Illinois (10).

In addition, it was assumed that the analyst has had sufficient knowledge of the local agriculture to supply realistic input-output coefficients where they were not available elsewhere.

METHOD OF ANALYSIS

The analytical method applied in this study is linear programming. This analytical procedure has become so widespread in use as to be almost commonplace in agricultural research wherever problems of profit maximization or cost minimization are involved.

Linear programming is a mathematical form of the early farm budgeting procedure. It involves solutions of simultaneous equations and most of its mathematical assumptions and principles of maximization were known before the development of the technique. With this method it is possible to analyze, in a fraction of the time used in budgeting, very large problems involving a great number of alternatives and situations which could not be solved with the budgeting procedure. Furthermore, linear programming gives "optimum" solutions whereas budgeting only gives "better" solutions on a "trial and error" basis.

At the present time, although the procedure has limitations and is far from being fully explored, it is being used in 41 Land Grant Colleges in research topics and in extension work in 14 of them (7).

Several linear programming models have been developed (7). The most important are the transportation model, variable price programming, dynamic programming, variable resource programming, and the general equilibrium model.

The model applied in this study is a profit maximization solution for a type of variable resource programming. In this model the optimum farm organization can be determined with one resource as a continuous variable, in this case capital, while the other resources are held constant.

Readers interested in the general theory of linear programming and in the details of the technique are referred to Dorfman, Samuelson and Solow (6) and to Heady and Candler (12).*

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*For application of linear programming to different agricultural economics problems see References 4, 13, 14, 20 and 26.

RESOURCES, ENTERPRISES AND INPUT-OUTPUT COEFFICIENTS

The scarce resources constraining any agricultural production process are land, labor, capital and management. They are outlined below as they applied to this project.

Land

Two farm sizes, 131 and 252 acres, were assumed for the study. They represent the modal size of farms between 62 and 360 acres* as indicated in the farm survey previously mentioned.

These two farm sizes constitute the land restriction for the first three objectives. This restriction is dropped for the fourth objective where practically unlimited land is assumed.

The 131-acre farm has 128 acres and the 252-acre unit 245 acres of cropland. The remaining land is occupied by fences, farmstead and roads.

In all cases it is assumed that soil types and other

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*In some other areas within Pergamino County the frequency distribution is represented by farms with larger size or by farms with smaller size than those indicated. However, the procedure applied in the study is not invalidated by the selection of these two sizes. First, a representation of the whole area is not attempted. Secondly, constant coefficients of production are assumed in linear programming and therefore resource inputs per acre of each enterprise or activity are the same regardless of size.

physical characteristics are homogeneous. Consequently there are no yield differences between the two farm sizes.

Labor

The current family labor supply is considered as the labor restriction for each farm size except for two situations in which additional labor can be hired at the prevailing wage.

The survey showed that the 128-acre farm has family labor of about 1.9 man equivalents, while the 245-acre farm has about 2.1 man equivalents per year. Thus 5844 hours of labor are available on the 128-acre farm and 6344 hours on the larger 245-acre unit.

From this labor an average of 20% was subtracted as indirect or overhead labor* to obtain the direct labor supply. Also different amounts must be subtracted to compensate for days when the weather does not permit work. Once these deductions are made the resulting figures indicate the true labor restriction. Tables 1 and 2 show the total and direct labor available in each case, by twelve-month periods. Only direct labor will apply to each specific enterprise in computing input-output coefficients. The hired labor

*Indirect or overhead labor includes labor devoted to buildings, fences, and machinery maintenance, business trips and pasture production.

Table 1. Total and direct operator and family's labor available per month on 128-acre farm

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Total operator labor	250	250	250	250	250	250	250	250	250	250	250	250	3000
Total housewife labor	37	37	37	37	37	37	37	37	37	37	37	37	444
Total other family labor	200	200	200	200	200	200	200	200	200	200	200	200	2400
Total labor available	487	487	487	487	487	487	487	487	487	487	487	487	5844
Less 20% indirect labor	97	97	97	97	97	97	97	97	97	97	97	97	1164
Hours of unfavorable weather	--	--	20	20	10	--	--	--	20	20	10	--	100
Total direct labor for crops and livestock production	390	390	370	370	380	390	390	390	370	370	380	390	4580

Table 2. Total and direct operator and family's labor available per month on 245-acre farm

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Total operator labor	250	250	250	250	250	250	250	250	250	250	250	250	3000
Total housewife labor	37	37	37	37	37	37	37	37	37	37	37	37	444
Total other family labor	325	325	325	200	200	200	200	200	200	200	200	325	2900
Total labor available	612	612	612	487	487	487	487	487	487	487	487	612	6344
Less 20% indirect labor	122	122	122	97	97	97	97	97	97	97	97	122	1264
Hours of unfavorable weather	--	--	20	20	10	--	--	--	20	20	10	--	100
Total direct labor for crops and livestock production	490	490	470	370	380	390	390	390	370	370	380	490	4980

alternative is permitted to enter the program only in Situations 1 and 2 in which a high labor consuming activity, poultry, is included. All enterprises, including poultry, are competitive for the labor supply.

The labor supply was grouped by monthly periods, instead of four or six farming seasons. Such a detailed breakdown may not have been necessary. However, the procedure was followed to permit more flexibility in planning. In addition, crop and livestock activities in Argentina have a wider dispersion seasonally than is true in the US cornbelt.

Capital

In the area under study, capital is one of the most important restrictions in developing farm programs directed toward increasing output and raising income by means of technological improvements.

Given the importance of raising the agricultural product of Argentina and finding resource combinations which maximize the utilization of other scarce resources, capital will be assumed as a non-limiting factor. Capital will be made available to the extent of its profitability. Under this assumption, optimum plans will not be stopped at any point because of a lack of capital and a range of plans with different quantities of capital will be determined.

The term, "operating capital", will be used to express the quantity of money required for annual operating expenses. It includes such costs as seed, insecticides, tractor operation and machinery repairs, livestock investment, feed, veterinary services and medicines. It does not include fixed costs like interest, taxes and depreciation on machinery, buildings, land and fences.

Returns computed in subsequent plans do not cover these fixed costs. Hence to obtain net farm income, fixed cost items should be subtracted for each optimum plan.

A further assumption of the study is that there is no restriction on housing space for beef production because mild weather conditions make housing unnecessary.

For swine production, movable houses will provide adequate shelter for young litters on pasture and can be made to serve equally well as farrowing pens. Another assumption is that the operator has adequate machinery for modern farm operation.

Management

The level of management available is set out by the production coefficients of each enterprise used in this study. It is assumed that the farmer can perform the farm operation required by each enterprise.

Prices

The determination of income depends on resource-product-price relationships, as well as on the physical productivity of the different factors. For this reason the accuracy and significance of prices used in linear programming have great importance and should be carefully investigated and related to an appropriate time period.

The prices of agricultural products in Argentina have been changing chaotically under the influence of external factors. Besides cyclical variations, the "normal" price relationships have been dislocated by alternative shifts from free market prices to systems of government control, multiple rates of exchange, establishment of bilateral trading, inflation, as well as several abnormal droughts. For these reasons the prices used in the study do not represent long run price ratios between farm products and factors purchased. Instead they represent average prices, paid and received by farmers for the year 1960. Cattle prices used are also average 1960 prices for the respective classes and grades.

The conclusions of this study in regard to optimum farm plans for the future will be limited by the relevance of these prices. The prices used in computing gross revenue and cost for the different enterprises are summarized in Table 3.

Table 3. 1960 current prices of various products and factors used for computing returns of alternative cropping and livestock systems

Item	Unit	Purchasing price, $	Selling price, $[a]
Seed			
Corn	bushel	3.08	---
Wheat	"	0.99	---
Oats	"	0.44	---
Sunflower	"	1.78	---
Alfalfa	pound	0.32	---
Feed and grain			
Corn	bushel	---	0.700
Wheat	"	---	0.863
Oats	"	---	0.360
Sunflower	"	---	1.518
Hay	ton	---	10.000
Cattle supplement	cwt	1.30	---
Hog supplement	"	2.60	---
Livestock and livestock products			
Beef			
Yearling steer (1100 lbs)	cwt	8.104	8.392
Medium yearling (950 lbs)	"	8.575	8.104
Calf (400 lbs)	"	---	8.575
Heifer	"	---	8.392
Cow	"	---	5.726
Brood cow	"	6.700	---
Baby beef (560 lbs)	"	---	9.650
Bull	unit	244.00	170.00

[a]Marketing costs were subtracted from market value to obtain net on-farm selling price. If market prices were used, an unrealistic grain-livestock price relationship would result. In general, livestock has a lower transportation cost relative to its price than has feed grain.

The weight and value of grains, livestock and other products and resources were transformed from quintal, kilogram, metric ton and pesos to bushels, pounds and dollars. The rate of exchange used for the monetary value was one dollar for each 82 pesos.

Table 3 (Continued)

Item	Unit	Purchasing price, $	Selling price, $[a]
Hogs			
225 lbs	cwt	---	11.862
Sow	"	---	9.201
225 lbs, two litter system	"	---	12.600
Sow (April)	"	---	9.600
Poultry			
Sexed chicken	head	0.340	---
Culled pullet	pound	---	0.166
Culled hen	"	---	0.166
Eggs	dozen	---	0.250

Yields

Accuracy in yield data has paramount importance in linear programming. Yields set the amount of grain and hay produced, the quantity of livestock that could be fed and consequently, the resulting income and optimum plans. Knowledge of the effect of crop rotations on yields, based on experiment station research, is essential to planning. Table 4 on pages 25 and 26 presents the yields assumed for each crop sequence.

The use of fertilizers is relatively unknown in Pergamino, consequently their application was not considered in this study. Also, under the present price ratio it is doubtful whether the marginal productivity of commercial fertilizer is sufficiently high to make its use profitable. In addition, available information on crop response to fertilizer in this type of farming is limited.

Description of Cropping and Livestock Enterprises

Natural and market conditions in the area of Argentina under study permit a wide range of cropping systems and livestock enterprises. Consequently, several combinations can be proposed in determining the system that brings the highest return. Having in mind that crops and livestock compete in the use of resources, especially land, a range from a high percentage of crops in relation to forages to a low percentage of crops relative to forage are considered in defining cropping activities. Livestock alternatives vary from high forage consumers, like beef cows, to high corn consumers, like hogs and poultry.

Cropping enterprises

The same cropping system could be applied to both farm sizes under study but some rotations would have a tendency to reduce the field sizes excessively. The 128-acre farm is assumed to be divided into 4 fields and the 245-acre farm into 6 fields of almost equal size. This division allows their cultivation without reducing their size to an inefficient scale.

For this reason only 5 rotations appeared to provide suitable alternatives for the 128-acre farm. They were:

Corn-wheat-alfalfa CWA

Corn-corn-wheat-alfalfa CCWA

Corn-wheat-sunflower-meadow CW(SF)M

Corn-oats-meadow COM

Corn-oats-meadow-meadow-meadow COMMM

In these alternatives, land is kept in corn only for 2 consecutive years before it is replaced by wheat and alfalfa.

Besides those mentioned above, six more rotations were considered for the 245-acre farms. They were:

Corn-corn-corn-corn-wheat-alfalfa CCCCWA

Corn-corn-wheat-sunflower-meadow CCW(SF)M

Corn-corn-corn-wheat-sunflower-meadow CCCW(SF)M

Corn-corn-corn-oats-meadow CCCOM

Corn-corn-oats-alfalfa-alfalfa-alfalfa CCOAAA

Corn-corn-corn-wheat-alfalfa CCCWA

The heaviest cropping system is represented by rotations including 4 consecutive years of corn. The rotation corn-corn-oats-alfalfa-alfalfa-alfalfa represents the highest percentage of forage produced.

Many farmers of the area have grown corn for more than 4 years in the same field. The extent that yields decline when land is cropped more intensively is unknown. For this reason, rotations with more than 4 years of corn crop were not introduced. Likewise for lack of information, several other cropping systems that perhaps are technically and economically feasible in the region were not taken into account. Those systems presented illustrate the effect on farm income of different proportions of forage in the rotation in combination with livestock enterprises.

Forage selling was not permitted to enter the program as an activity, since hay, due to its complementary position in the cropping system, is a surplus commodity in the area. Forage crops were included in all of the alternative rotations because of their role in maintaining soil fertility.

Corn was included in all programs because it is the predominant crop in this area, is climatically well adapted and consistently provides high returns.

Finally, in these programs, all corn and hay produced on the farm can be fed to livestock, but neither of the products can be purchased. Thus their availability may limit livestock production and consequently returns to the operation. Yields under all rotations considered in alternative plans are given in Table 4. Percentages of grain crops and forage are shown in Table 5.

By comparing Table 5 with Table 4 it can be seen that as the percentage of forage crops and pasture increases in the rotation, grain yields also increase as a consequence of high-

Table 4. Average annual crop yields for alternative cropping systems

Cropping system	C				W	O	SP	A	M	P[a]
	1st yr.	2nd yr.	3rd yr.	4th yr.						
	bu.	bu.	bu.	bu.	bu.	bu.	bu.	ton	AUM[b]	AUM
CWA	52	--	--	--	25.5	--	--	2.5		0
CCWA	50	46	--	--	24.5	--	--	2.5		0.3
CCCWA	48	43	38	--	23.5	--	--	2.5		0.6
CCCCWA	46	40	34	28	22.5	--	--	2.5		0.9
CW(SP)M	48	--	--	--	24.5	--	16	---	3.4	0
CCW(SP)M	46	40	--	--	23.5	--	16	---	3.4	0.3
CCCW(SP)M	40	36	30	--	22.5	--	15	---	3.4	0.6

[a]Additional pasture between crops.

[b]The production and consumption of grazing is measured in terms of animal unit months (AUM) in some crop and livestock budgets. The AUM is defined as the amount of grazing required by one animal unit for one month, one animal unit being one mature cow.

Different kinds of livestock are converted to animal units on the basis of weight as follows: $AU = \frac{\text{Average weight of animal}}{1000}$.

The AUM in Pergamino is given by

$$\frac{\text{12 months x 0.7 (AU capacity per hectare)}}{\text{2.47 (One hectare = 2.47 acres)}} = \text{3.47 AUM per acre.}$$

Table 4 (Continued)

Cropping system	C				W	O	SF	A	M	P[a]
	1st yr.	2nd yr.	3rd yr.	4th yr.						
	bu.	bu.	bu.	bu.	bu.	bu.	bu.	ton	AUM[b]	AUM
COM	48	--	--	--	----	30	--	---	3.5	0
CCCOM	44	38	32	--	----	28	--	---	3.5	0.6
CCOAAA	52	50	--	--	----	30	--	2.8		0.3
COMMM	50	--	--	--	----	30	--	---	3.5	0

Table 5. Annual acreages of crops, in percent, for alternative cropping systems

Cropping system	Corn	Wheat	Oats	Sun-flower	Alfalfa	Meadow
CWA	33.3	33.3	----	----	33.3	----
CCWA	50.0	25.0	----	----	25.0	----
CCCWA	60.0	20.0	----	----	20.0	----
CCCCWA	66.6	16.7	----	----	16.7	----
CW(SF)M	25.0	25.0	----	25.0	----	25.0
CCW(SF)M	40.0	20.0	----	20.0	----	20.0
CCCW(SF)M	50.0	16.7	----	16.7	----	16.7
COM	33.3	----	33.3	----	----	33.3
CCCOM	60.0	----	20.0	----	----	20.0
COMMM	16.7	----	16.7	----	----	66.6
CCOAAA	33.3	----	16.7	----	50.0	----

er soil fertility under these systems. Nevertheless total grain production is lower with the higher forage systems.

The most common system presently in use is given in Table 6. It will be compared later with the optimum plans which result from the linear programming process.

The cropping system now commonly followed by the farmer in the 128-acre farm represents a rotation of CCS(SF)A with 22% of the land in grass and legumes. The most common system followed in the 245-acre farm is a rotation of CW(SF)A with

Table 6. Present systems of farming operation, level of operating capital and returns

Cropping and livestock system	Size			
	128 acres	%	245 acres	%
Corn (acre)	50	39	58	24
Wheat (acre)	27	21	64	26
Sunflower (acre)	23	18	60	24.5
Alfalfa (acre)	25	20	43	27.5
Pasture (acre)	3	2	20	8
Beef cow calves sold (head)	5		14	
Hogs (one spring litter)	1		3	
Level of operating capital used ($)	1000		2450	
Returns to labor, capital and management ($)	2515		4801	

35.5% of the land in grass and hay crops.

Livestock enterprises

Climate and natural conditions of the area are favorable for livestock production. Winters are mild and temperatures during the summer are not extreme. With a suitable rotation system it is possible to graze livestock the year around. Therefore, a large number of livestock systems could have been introduced for comparison in the study, but only a few were considered. These are not complex systems and can be found on many farms in the Pergamino area. A higher level of managerial skill was introduced in the calculation of input-output coefficient for the programming procedure than is typical in the area. However, the typical farmer of the region has sufficient skill to accept these improvements without undue changes in his present customs and preferences.

Some livestock activities were expressly excluded as alternatives, i.e. dairy. In order to be successful, dairy requires a level of management which it is assumed can not be found in the region. In addition, transportation facilities for efficient delivery of perishable products to distant markets are not yet adequate. Therefore, production of milk in competition with better geographically located areas did not seem logical.

Following is a summary of ten livestock systems considered as alternatives competing for resources:

Beef enterprise

Beef cow calves sold In this system calves are usually dropped in the spring, early September. They receive no creep feed, and are marketed during the fall, about April 10. Alfalfa hay replaces one-half AUM of grazing, especially during winter months. A 90% calf crop is assumed. (See Appendix, Table 25.)

Beef cow calves fed* In this activity calves are dropped in May and marketed the next February. The winter ration for the herd is almost the same as in the previous beef cow system, but calves receive creep feed consisting of about 12.5 bushels of corn. Also they graze, receiving 1.5 AUM of pasture. With this additional feed, calves weigh an average of 560 pounds at market time. (See Appendix, Table 26.)

Yearling steers In this system stock animals are bought from local sources in October. Average purchased weight is about 500 pounds. Yearlings are sold in the late summer, February, at an average weight of 725 pounds. The feeding ration is primarily roughage with some concentrate during the first three months. The animals are marketed directly from grass. (See Appendix, Table 27.)

Two-year-old steers These animals are bought at 725 pounds during the late summer, and are kept the year round on pasture. The winter ration while on pasture consists of supplement and hay. A gain to an estimated weight of 1150 pounds by market time is expected. (See Appendix, Table 28.)

Full fed steers In this system good grade yearling steers are bought weighing about 778 pounds at the

*Information for this enterprise was obtained from Reference 25.

beginning of fall. They are grazed on oats or other equivalent pasture for 120 days and full fed in a dry lot for another 75 days with corn, hay and supplement. The animals are marketed after 195 days with an expected weight of 1183 pounds. (See Appendix, Table 29.)

Hog enterprises

One spring litter In this system average spring hogs on pasture are fed 423 pounds of grain and supplement per 100 pounds of pork produced. Seven pigs are weaned per litter and 5.72 hogs are marketed per unit. Each 100 pounds of output includes 82 pounds of market hog and 18 pounds of sow. (See Appendix, Table 30.)

One fall litter The same input-output relationship was assumed in this system as for spring hogs. However, this activity was included as an alternative because the monthly distribution of labor required is quite different from the spring system. Monthly labor being a restriction, different enterprise combinations are possible with different monthly labor requirements. (See Appendix A, Table 30.)

Two litters In this system pigs are farrowed twice during the year. One litter is farrowed in spring and one in fall. The number of pigs weaned per unit (two litters) is 14.6; the number of hogs marketed per unit (two litters) is 13.02. Hogs are fed 498 pounds of grain and supplement plus pasture per 100 pounds of pork produced. Each 100 pounds of pork marketed includes 90 pounds of hog and 10 pounds of sow. (See Appendix, Table 30.)

Feeder pigs   Pigs are purchased weighing 40 pounds, and fed 112 bushels corn, 0.3 tons hay and 800 pounds supplement per unit of 10 pigs. They are sold weighing 220 pounds. (See Appendix, Table 31.)

Laying flock   A commercial laying flock is proposed as an alternative activity in two situations. Twelve sexed chicks are purchased for each final productive unit of ten laying hens to replace the old laying flock each year. One cull pullet, 8.5 cull hens and 150 dozen eggs are sold from each unit of 10 hens. This enterprise is considered competitive for each resource, including labor. (See Appendix, Table 32.)

All enterprises described above are summarized in Table 7.

Resource Levels and Input-Output Coefficients

The determination of basic input-output data or coefficients of production is the most important step in linear programming. The validity of programs obtained with this technique will largely depend on the accuracy of the coefficients.

Input coefficients indicate the quantity of each resource, land, labor, capital, which is required per unit of

Table 7. Enterprises included as alternatives in the study

Enterprise number	Enterprise
P1	Rotation corn-wheat-alfalfa
P2	Rotation corn-corn-wheat-alfalfa
P3	Rotation corn-corn-corn-wheat-alfalfa
P4	Rotation corn-corn-corn-corn-wheat-alfalfa
P5	Rotation corn-wheat-sunflower-meadow
P6	Rotation corn-corn-wheat-sunflower-meadow
P7	Rotation corn-corn-corn-wheat-sunflower-meadow
P8	Rotation corn-oats-meadow
P9	Rotation corn-corn-corn-oats-meadow
P10	Rotation corn-corn-oats-alfalfa-alfalfa-alfalfa
P11	Rotation corn-oats-meadow-meadow-meadow
P12	Beef cow calves sold
P13	Beef cow calves fed
P14	Yearling steers
P15	Two-year-old steers
P16	Full fed steers
P17	Hogs, one spring litter
P18	Hogs, one fall litter
P19	Hogs, two litters
P20	Feeder pigs
P21	Laying flock

product. For example, the annual cash expenses to produce one bushel of corn is the capital input coefficient for corn. The feed consumed per unit of hogs under the one litter system is the feed input coefficient for the one litter system. The labor required, in any month, for each unit of a particular crop or livestock enterprise is the labor coefficient for the month being considered. Land coefficients are found in the same way. Coefficients of production are assumed constant in linear programming. This means that coefficients are used in the same proportion in producing successive units of products. If rotation CWA requires 0.1639 unit of $100 capital for each one unit of 3 acres, and 0.196 unit of May labor, it will require 0.2878 unit of $100 capital and 0.392 unit of May labor for two units of 3 acres of rotation.

Direct labor requirements for crops are given in Table 8 and for livestock in Table 9. The quantities of each resource used to produce one unit of output of each activity are given in Table 10.

Table 8. Direct labor requirements in hours per acre, by months and total for year, for crops

Crop	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Corn	0.13	--	--	--	1.67	--	--	1.13	0.51	0.29	0.46	--	4.186
Wheat	--	--	--	0.63	0.29	0.37	--	--	--	0.13	--	1.13	2.546
Oats	--	0.63	0.50	--	--	--	--	--	--	--	1.13	--	2.259
Sun-flower	0.13	--	1.13	--	--	--	--	0.63	0.42	0.29	--	--	2.592
Alfal-fa	1.57	0.26[a]	0.10[a]	1.57	--	--	--	--	1.57	--	1.57	--	

[a]These are times for plowing, disking, harrowing and drilling, used only once each five years. They were obtained by dividing the total labor used in these operations by five.

Table 9. Direct labor requirements in hours per unit by months and for year for livestock

Enterprise[a]	Jan.	Feb.	Mar.	Apr.	May	June
P12	.10	.08	.10	.25	.25	.50
P13	.44	.08	.42	.85	1.10	.94
P14	.10	.10	---	---	---	---
P15	.18	.34	.18	.18	.21	.21
P16	---	---	.18	.10	.18	.28
P17	1.755	1.755	1.675	1.675	1.660	1.658
P18	0.920	1.861	3.200	3.119	2.890	2.890
P19	3.370	4.943	4.269	3.370	2.921	2.921
P20 (10 units)	---	---	---	4	4	4
P21 (10 hens)	1.1325	0.9815	0.9815	1.2080	1.0570	1.0570

[a]See Table 7, page 33, for description of enterprises.

Table 9 (Continued)

Enterprise[a]	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
P12	.92	1.37	1.45	1.02	.10	.36	6.50
P13	.50	.78	.60	.66	.30	.28	6.95
P14	---	---	---	.28	.10	.18	0.76
P15	.21	.21	.21	.10	.18	.10	2.31
P16	.28	.28	.10	---	---	---	1.40
P17	1.675	1.675	2.045	2.160	1.950	1.755	21.238
P18	2.310	1.631	1.626	1.032	1.038	1.185	23.702
P19	3.595	6.292	4.719	3.146	2.697	2.697	44.940
P20 (10 units)	4	4	---	---	---	---	20.00
P21 (10 hens)	1.0570	1.0570	1.6610	1.8120	1.8120	1.2835	15.1

Table 10. Basic resource requirements (input-output coefficients) for the various enterprises (valid for all situations in which the enterprise is used as alternative)

Resource	Enterprise[a]										
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Net price[b] ($)	49.83	75.24	92.99	100.90	67.60	88.81	96.76	37.78	73.66	71.00	39.18
Land (acres)	3	4	5	6	4	5	6	3	5	6	5
Capital[c] ($100)	0.1439	0.1890	0.2341	0.2792	0.1143	0.1549	0.2045	0.0768	0.1670	0.1801	0.0768
Labor (hours)											
January	1.703	1.833	1.963	2.093	0.260	0.390	0.520	0.130	0.390	4.978	0.130
February	0.256	0.256	0.256	0.256	0	0	0	0.625	0.625	1.393	0.625
March	0.100	0.100	0.098	0.098	1.130	1.130	1.130	0.504	0.504	0.798	0.524
April	2.198	2.198	2.198	2.198	0.625	0.625	0.625	0	0	4.719	0
May	1.962	3.632	5.302	6.972	1.962	3.632	5.302	1.670	5.010	3.340	1.670
June	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0
August	1.128	2.256	3.384	4.512	1.753	2.881	4.009	1.128	3.384	1.128	1.128
September	2.084	2.595	3.106	3.617	0.926	1.433	1.948	0.511	1.533	2.595	0.511
October	0.417	0.709	1.001	1.293	0.709	1.001	1.293	0.292	0.876	0.584	0.292
November	2.028	2.483	2.938	3.393	0.455	0.910	1.365	1.580	2.490	6.759	1.580
December	1.130	1.130	1.130	1.130	1.130	1.130	1.130	0	0	0	0
Feed											
Corn eq.[d] (100 bu)	0.520	0.960	1.290	1.480	0.480	0.860	1.060	0.630	1.280	1.170	0.650
Hay eq.[e] (tons)	2.500	2.600	2.700	2.800	1.200	1.300	1.400	1.600	1.800	8.500	4.200

[a]See Table 7, page 33, for description of enterprises.

[b]Net price is equivalent to the net revenue produced by one unit of activity. The net revenue for any activity is equal to the gross revenue minus the variable costs of producing these activities. In this study, rotations are credited with the value of crop produced. For this reason the selling activity has zero price and need not be included as a separate activity.

[c]Capital includes only annual cash expenses.

[d]Amount of corn equivalent produced from and consumed by one unit of activity.

[e]The production of oats of each rotation was converted as a corn equivalent at the rate of 1 bu. oats = 0.50 bu. corn. AUM were converted to a hay equivalent at the rate of 1 AUM = 0.36 ton hay equivalent.

Table 10 (Continued)

Resource	P12	P13	P14	P15	P16	P17	P18	P19	P20[f]	P21[g]
	Enterprise[a]									
Net price[b]	33.58	35.08	14.36	30.20	22.49	77.16	77.16	164.83	103.72	23.956
Land (acres)	0	0	0	0	0	0	0	0	0	0
Capital[c] ($100)	0.9799	1.0690	0.4381	0.6535	0.7580	1.3582	1.3582	2.3016	1.4941	2.8057
Labor (hours)										
January	0.100	0.440	0.100	0.180	0	1.755	0.920	3.370	0	1.132
February	0.080	0.080	0.100	0.340	0	1.755	1.861	4.993	0	0.982
March	0.100	0.420	0	0.180	0.180	1.575	3.200	4.269	0	0.982
April	0.250	0.850	0	0.180	0.100	1.675	3.119	3.370	4.000	1.208
May	0.250	1.100	0	0.210	0.180	1.660	2.890	2.921	4.000	1.057
June	0.500	0.940	0	0.210	0.280	1.458	2.890	2.921	4.000	1.057
July	0.920	0.500	0	0.210	0.280	1.675	2.310	3.595	4.000	1.057
August	1.370	0.780	0	0.210	0.280	1.675	1.631	6.292	4.000	1.057
September	1.450	0.600	0	0.210	0.100	2.045	1.626	4.719	0	1.661
October	1.020	0.660	0.280	0.100	0	2.160	1.032	3.146	0	1.812
November	0.100	0.300	0.100	0.180	0	1.950	1.038	2.697	0	1.812
December	0.360	0.280	0.180	0.100	0	1.755	1.185	2.697	0	1.283
Feed										
Corn eq.[d] (100 bu)	0	0.125	0	0	0.150	1.120	1.120	2.030	1.120	0.112
Hay eq.[e] (tons)	4.400	4.900	1.800	4.350	1.530	1.000	1.000	1.400	0.300	0.100

[f] Feeder pigs are taken in units of ten.

[g] The laying flock is considered competitive with other enterprises with respect to labor.

ANALYSIS AND PRESENTATION OF RESULTS AND OPTIMUM PLANS

Optimum plans for different capital levels have been computed in each of the eight farm situations listed in Table 11. Forty-six possible plans were obtained for the first six situations and one plan each for the remaining two situations.

For all situations and levels of capital, the input-output coefficients were kept fixed throughout the computation. Only the resource restrictions were changed. Capital was used at variable levels within the first situations; land was restricted at two levels (128 and 245 acres). A labor hiring activity enters only in Situations 1 and 2. All the situations have been determined under the restriction that forage and grain for feeding livestock must be produced on the farm. Corn and hay can not be purchased to expand livestock production beyond the limits established by the production of the farm. Hence, any livestock program coming into the plan can not consume more than the grain and forage produced on the farm. At least one crop activity producing corn and hay must appear in any plan which includes a livestock activity.

In Situations 1 and 2, the labor restriction was removed. The assumption was made that all additional labor needed to

Table 11. Resource levels and other characteristics for the farm situations studied

Situation	Farm size, acres	Capital level	Labor	Other characteristics
1	128	Variable	Full time family; extra hired labor if necessary	Includes only rotations CWA, CCWA, CW(SF)M, COM, COMMM. Includes all livestock enterprises.
2	245	"	"	Includes all rotations. Includes all livestock enterprises.
3	128	"	Full time family; no hired labor	Includes only rotations CWA, CCWA, CW(SF)M, COM, COMMM. Includes all livestock enterprises except laying flock.
4	245	"	"	Includes all rotations. Includes all livestock enterprises except laying flock.
5	128	"	"	Includes only rotations CWA, CCWA, CW(SF)M, COM, COMMM. Does not include laying flock or hog enterprises.

Table 11 (Continued)

Situation	Farm size, acres	Capital level	Labor	Other characteristics
6	245	Variable	Full time family; no hired labor	Includes all rotations. Does not include laying flock and hog enterprises.
7	Non-limiting	Non-limiting	Full time family; labor as on 245-acre	Includes all rotations. Includes all livestock enterprises except laying flock.
8	Non-limiting	Non-limiting	"	Includes all rotations. Does not include laying flock and hog enterprises.

maximize profits from the available supply of land and capital for each plan would be obtainable by hiring labor at the current wage.

The manner in which crop and livestock enterprises come into optimum plans for different capital levels in each situation is shown in Tables 12, 14, 16, 18, 20 and 22. These tables are included following the description of each situation.

Enterprises and resources are listed on the left margin of these tables, while different capital levels are shown to the right of the margin. Information is given concerning corn and hay production, unused labor by month, the corn equivalent sold, unused hay, and the returns to labor, capital and management. The restriction which limits further expansion of the plan is also designated for each plan.

Plans resulting from the programming procedure of each situation are discussed in detail in the following pages.

Situation 1: Optimum Plans for 128-Acre Farm, With Varying Levels of Capital, Permitting Hired Labor and Including 5 Crop Rotations and 10 Livestock Enterprises

Plan 1

When operating capital is used at the lowest level ($365 in Plan 1), the optimum plan includes only 128 acres of rotation CW(SF)M. No livestock activity enters at this capital level because crops give the highest returns to limited capital. Therefore, no corn or hay is fed on the farm and all grain is sold. This results in a return to labor, capital and management of $2163. In addition, 38.4 tons of hay will go unused. The operator hires no labor since the system uses only 263 hours of labor from the annual man-hour supply of 4560.

Plan 2

When the level of capital increases to $605,* rotation CW(SF)M is eliminated from the optimum plan, and 128 acres of rotation CCWA takes its place. Again, no livestock enterprise enters at this low level of operating capital. Rotation CCWA is the most profitable activity. Three thousand and seventy bushels of corn are produced and sold. Also, 83.1 tons of hay are unused. Returns to labor, capital and management are $2407. Man hours of labor used increase to 543 hours out of the total annual supply of 4560 hours.

Plan 3

With the increase of operating capital to $5258, the same rotation, CCWA, enters the plan. A laying flock of 1658

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*These odd levels of operating capital are given by the successive "corners" or interactions in the computation of the variable resource program. These corners represent, on the production possibility curves, each magnitude of capital where the enterprise included in the optimum plan changes.

hens is also included. Crop production is the same as under the previous situation, but with a corn consuming activity, the laying flock, only 1210 bushels of corn out of 3070 bushels produced and 66.6 tons of hay out of 83.1 tons produced are at the farmer's disposal. Returns to labor, capital and management increased to $6381. Annual labor use is 3048 hours. Feed grain and hay are still available in large quantities and do not limit the production at this level of capital. A new feature in this plan is that November labor became a restriction to the production process. No more capital investment can be made without hiring extra labor in November.

There is a substantial difference in operating capital requirements between Plans 2 and 3. This does not necessarily mean that such a high level of capital is essential to the introduction of poultry to a plan. Between Plan 2 using $605 of capital and Plan 3 using $5258 of capital, many plans using intermediate amounts of money and producing intermediate levels of poultry are feasible. According to the assumptions of linearity and constant relationship, these plans can be found by simple algebraic or graphic procedures without further extending the linear programming computations.*

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*For example, if the number of hens which would be produced with $1000 of capital is desired, it can be found in this way: with $4653 (the difference between $605 of capital used by Plan 2 and $5258 used by Plan 3) a laying flock of 1658 hens can be produced, with $395 of capital (the differ-

Plan 4

If a higher level of capital, $7658, is used, no major changes are introduced except for an expansion of the laying flock activity to 2480 birds. The same rotation, CCWA, is produced. The labor supply is exhausted during several months and additional labor must be hired in September, October and November. Two hundred sixty bushels of corn equivalent are sold. Returns to labor, capital and management for this plan are $8256.

Plan 5

At a capital level of $8447, the number of laying hens in the plan increases to 2744. The same rotation, CCWA, is included and all corn produced is consumed by the poultry enterprise. Thus, corn production becomes an effective restriction on the size of the laying flock. Labor must be hired in April and May. Hay is still available in large amounts. Returns to labor, capital and management are $8837.

Plan 6

In spite of the restriction imposed by total utilization of the corn produced in the previous plan, returns can be

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ence between $1000 used by the new plan and $605 used by Plan 2) x hens can be produced, equal to 140 laying units.

The same answer can be found with the graphic method. Looking at Figure 1, a vertical line is drawn from the $1000 point on the horizontal axis. It will intersect the laying flock line or activity curve for this enterprise at the 140 unit axis. This method holds true for each desired amount of capital, plan or factor in consideration.

expanded by the utilization of more operating capital. As the level of capital is increased to $9287, a beef cattle enterprise of 13 two-year-old steers enters the plan in addition to the 2744 hen laying flock in Plan 5. Cattle of this type utilize hay not used in the previous plans. No additional labor in relation to Plan 5 must be hired to add to the beef enterprise.

Corn and hay become restrictions on this plan. Some labor still remains unused in January, February, March, June, July and August. Returns to labor, capital and management are increased to $9222.

<u>Plans 7 and 8</u>

With $9349 of capital, in addition to the laying flock and crop enterprises indicated for Plan 6, the beef cattle enterprise which will enter the plan consists of 4 yearling and 11 two-year steers. By this means, returns are increased slightly to $9229. In Plan 8, at the $9809 capital level, the beef enterprise which will bring the highest returns along with the laying flock and rotation CCWA, is a herd of 41 yearling steers.

In both plans the corn and hay produced on the farm is fully utilized by the livestock enterprises. Beyond the level of $9808, no addition of capital can cause non capital resources to be reallocated in a more profitable manner.

Details of these plans can be observed in Table 12.

Table 12. Situation 1: optimum plans for eight levels of capital, 128-acre farm

Item	Plan 1	2	3	4	5	6	7	8
Level of capital ($)	365	605	5258	7658	8447	9287	9349	9808
Crop rotations (acre)								
CWA								
CCWA		128	128	128	128	128	128	128
CW(SF)M	128							
COM								
COMMM								
Beef cattle (head)								
Beef cow calves sold								
Beef cow calves fed								
Yearling steers							4	31
Two-year-old steers						13	11	
Full fed steers								
Hogs (litter)								
One spring litter								
One fall litter								
Two litters								
Feeder pigs (head)								
Poultry (bird)								
Laying flock			1658	2480	2744	2744	2744	2744
Corn eq. produced (bu.)	1530	3070	3070	3070	3070	3070	3070	3070
Hay eq. produced (ton)	38.4	83.1	83.1	83.1	83.1	83.1	83.1	83.1

Table 12 (Continued)

Item	Plan							
	1	2	3	4	5	6	7	8
Unused manhours (monthly)								
January	382	331	143	50	21	18	18	18
February	390	382	220	138	112	108	108	109
March	333	367	204	123	97	95	95	97
April	350	299	99	0	0	0	0	0
May	317	264	88	1	0	0	0	0
June	378	378	202	116	88	85	85	88
July	390	390	215	128	100	97	97	100
August	373	318	142	56	28	25	25	28
September	340	287	11	0	0	0	0	0
October	247	347	47	0	0	0	0	0
November	365	300	0	0	0	0	0	0
December	353	354	141	36	2	0	0	0
Hired labor hours (monthly)								
January								
February								
March								
April					32	32	32	32
May					26	26	26	23
June								
July								
August								
September				126	169	169	168	166
October				102	150	150	151	151
November				152	197	197	197	198
December								3

Table 12 (Continued)

Item	Plan 1	2	3	4	5	6	7	8
Used manhours (annual)	283	543	3048	4292	4628	4648	4649	4693
Corn eq. sold (bu.)	1530	3070	1210	260	0	0	0	0
Unused hay eq. (ton)	38.4	83.1	66.6	58.1	55.7	0	0	0
Return to labor, capital and management ($)	2163	2407	6381	8256	8837	9222	9229	9279
Limiting resources	Cap. Land	Cap. Land	Cap. Land	Cap. Land	Cap. Land Corn	Cap. Land Corn Hay	Cap. Land Corn Hay	Cap. Land Corn Hay

<u>Effects of different levels of capital with farm size constant and labor supply allowed to vary</u>

At the lowest level of capital considered ($365 for Plan 1) 128 acres of rotation CW(SP)M is the most profitable activity. As capital is increased to the second level of $605, another rotation, CCWA, comes into the plan, replacing the first one. With these two systems of operation, the labor of more than one entire man equivalent* could be retired from the farm without affecting the production process.

At the two preceding levels, capital is so limiting that it would not be profitable to purchase livestock units to consume the feed produced on the farm. Increasing the level of capital as in Plan 3, a laying flock comes into the program utilizing large amounts of feed, and most of the family labor supply, during some periods. From this point on, hiring additional labor would be necessary in increasing the scale of the production process by investing more capital. The investment of more capital brings greater output, higher returns and causes the optimum plans to become more diversified.

However, determining the optimum level of capital use when funds must be borrowed requires an estimate of the productivity of capital. When marginal value productivity of

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*Means one man working ten hours a day during 25 days per month and 12 months per year.

capital is equal to the interest rate paid for borrowed capital, the optimum level has been achieved.

At the lowest level of capital ($365) a return of $5.92 for each dollar invested is realized. For the $240 additional investment in Plan 2 there is a return of $1.01 per dollar. Other marginal productivities of capital are given in Table 13.

Operating capital can be borrowed from local banks in short term loans at an annual rate of 12%. The estimates of capital productivity derived from the programming procedure indicate that returns can be increased by borrowing capital on those farms where the profit maximization is the chief objective only to Plan 6, in which the marginal productivity of capital is 44 cents for each dollar invested. In Plans 7 and 8, the marginal productivity of capital is only 11 cents and 10 cents for each dollar invested. Therefore the farmer could not conveniently borrow capital which will bring returns smaller than the interest rate that he has to pay for each dollar borrowed.

In order that the results may be adapted to levels of capital other than those specifically indicated for each plan, a graphic illustration is presented.

The solution for Situation 1 is presented in Figure 1. The horizontal axis refers to levels of capital between zero and $9808, while the vertical axis refers to amounts of real

Table 13. Situation 1: marginal productivity of capital

Plan no.	Level of capital	Returns	Marginal productivity
1	365	2163	5.92
2	605	2487	1.01
3	5258	6381	0.85
4	7658	8256	0.78
5	8447	8837	0.73
6	9287	9222	0.44
7	9349	9229	0.11
8	9808	9279	0.10

activities coming into the plans, for example, acres of rotation and units of livestock. The number of man hours required at each capital level, total income and the marginal productivity of capital are also shown. Dotted vertical lines on the figure correspond to each corner or level of capital used in each different plan. Vertical lines at any desired level of capital between 0 and 9808 show the optimum programs for intermediate capital levels at the intersection points with the activity curves. However, it must be pointed out that levels of capital should be chosen where the plan is realistic. For example, with $650 of capital and 128 acres of rotation CCWA, only 16 laying hens are introduced into the plan. Hence this activity is not carried out on a practical

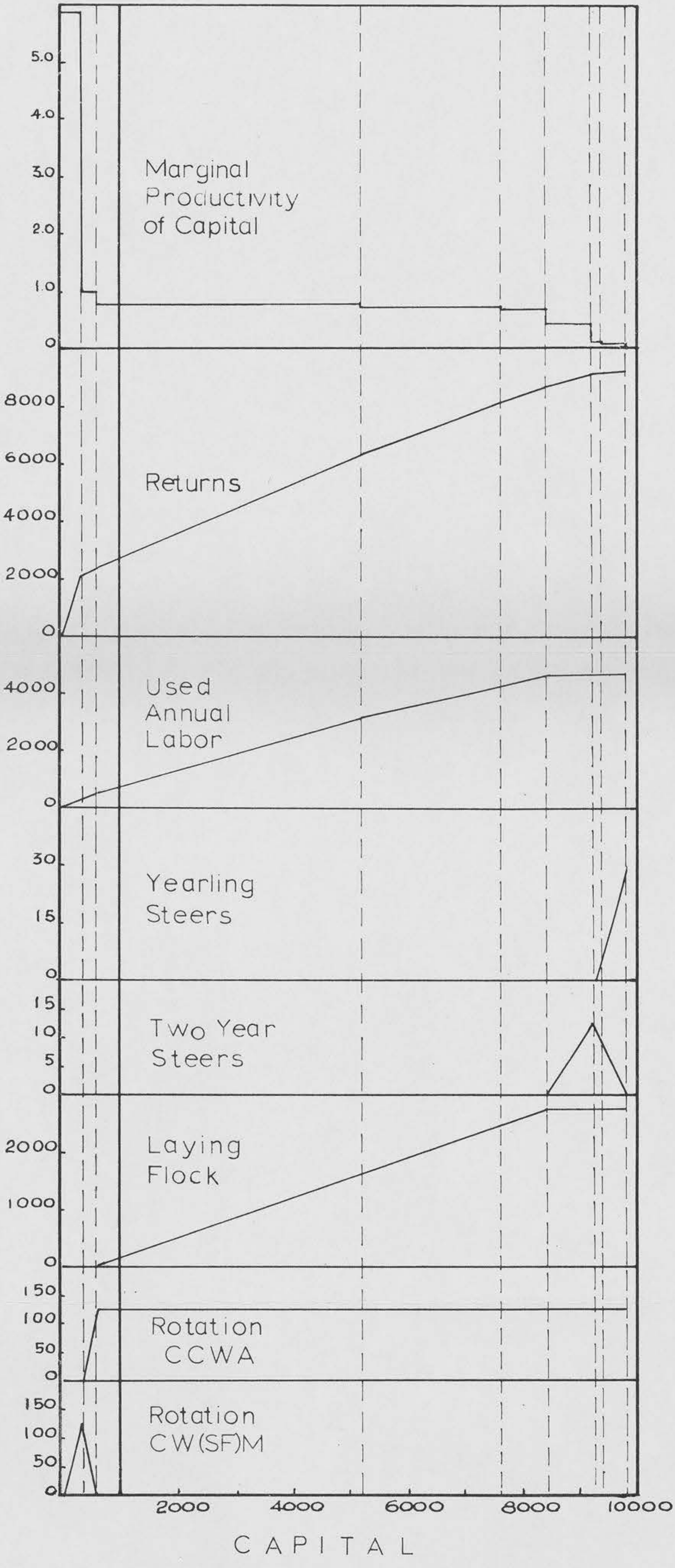

Figure 1. Graphic representation of Situation 1

scale with this amount of capital and would in all probability be dropped from the plan by any farmer.

The slope of the activity curve also has another economic interpretation. Between $365 and $605 of capital level, rotation CW(SF)M has a negative slope, while rotation CCWA has a positive slope. This means they are competitive enterprises for the use of land, capital and labor within that capital range.

Rotation CCWA has zero slope between $605 and $9808 of capital, while the laying flock activity curve has positive slope between capital levels $605 to $8447. Therefore, they are supplementary enterprises within this range.

A graphic presentation of the relative importance of the different capital levels on enterprise combination and returns for Situation 1 is also shown with detail in Figure 2, in which all plans presented in Table 12 are indicated by each "corner" point on the return line 0 P_8. Returns are indicated on the vertical axis and the levels of capital on the horizontal axis. The returns contributed by each enterprise in each particular optimum plan are indicated by the vertical distance between the boundary lines for each enterprise. For example, at P_3, returns are given by the combination of the rotation CCWA and the laying flock. Of the total amount of $6381, two thousand four hundred dollars are made from the rotation and the difference of $3981 can be

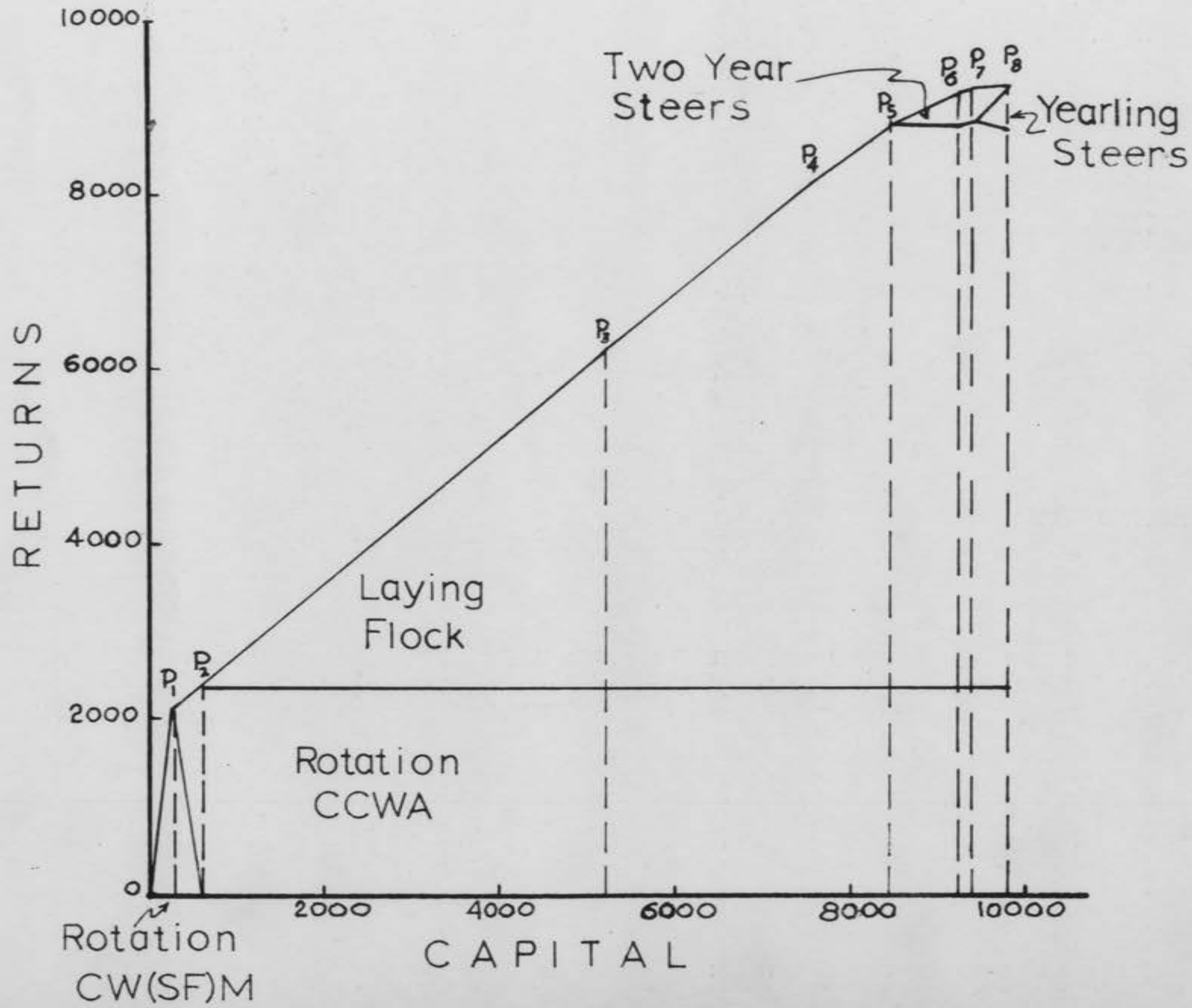

Figure 2. Source of returns, Situation 1

credited to the laying flock.

The graphic presentation of Situation 1 in Figure 2 indicates that the laying flock contributes on returns the most from the $3940 level of capital on up.

<u>Comparison of program plans to the system typically followed in the area</u>

In comparing the actual plan followed by the average farmer of the area in the 128-acre farm using $1000 of capital level with the optimum plan obtained in the study at the same level of capital, the following differences are found:

a. The rotation system used at the present time, CCW(SF)A, is replaced in the optimum plan by a system producing greater quantities of corn as in rotation CCWA.

b. The beef cow-hog combination produced in the actual plan is replaced by about 145 laying hens in the optimum plan.

c. The new crop-livestock combination which enters the plan causes returns to be increased from $2515 in the present system operated by the farmer to $2745 in the optimum plan.

Situation 2: Optimum Plans for the 245-Acre Farm, With Varying Levels of Capital, Allowing for Hired Labor and Including 11 Crop Rotations and 10 Livestock Enterprises

Situation 2 differs from Situation 1 in farm size, amount of family labor supply and because the farmer operating the 245-acre farm has a wider range of crop alternatives than the farmer in Situation 1. Eleven crop rotations are considered as alternatives in this situation as compared to only 5 in Situation 1.

Plan 1

When only enough capital to crop the land, $700, is available, the optimum plan again includes only one crop activity, 245 acres of rotation CW(SF)M. Therefore the total amount of 2940 bushels of feed grain produced can be sold, along with wheat and sunflower seed. This gives a $4140 return to labor, capital and management. Hired labor is not needed in this plan, as only 596 hours of labor out of an annual supply of 5000 hours are used.

Limiting resources are capital and land.

Plan 2

In raising the capital level to $759, 245 acres of rotation CCW(SF)M displace rotation CW(SF)M in the optimum plan. No livestock enterprises enter the plan. A total of 4213 bushels of corn are produced and sold, 695 hours of labor are used and returns to labor, capital and management amount to $4351.

Limiting resources to the production process are still capital and land. When capital is limited, other fixed resources like labor are not fully used. In this plan, as in Plan 1, one man equivalent can be withdrawn from the farm without restricting the plan during any months except May and August.

Plan 3

With $5728 of capital, a laying flock comes into the optimum plan, along with the same rotation, CCW(SF)M, which appeared in the previous plan. The laying flock includes 1770 birds which consume 1982 bushels of corn out of 6213 bushels produced by the rotation on the farm. Approximately 18 tons of hay equivalent are also consumed by the livestock enterprise.

Returns to labor, capital and management are $8549, and 3362 hours of labor are required. At this point October family labor is fully utilized and plans using more labor in this period could not be expanded without hiring additional labor.

Plans 4, 5 and 6

After Plan 3, the production process follows the same pattern through Plans 4 to 6. The same rotation CCW(SF)M, and the same livestock enterprise, laying hens, enter in these plans. As capital increases, more corn, hay and labor are used. A new feature in Plan 6 is that with $11,321 of capital, all the corn produced on the farm is consumed by the laying flock of 3636 hens.

Details about Plans 4, 5 and 6, inputs used and output produced are presented in Table 14 and Figure 3.

Plan 7

Since all the corn produced in Plan 6 by the rotation CCW(SF)M is consumed by the poultry enterprise, plans could not be expanded by addition of more capital, without a shift in the cropping program. Hence, in Plan 7 with $14,105 of capital, the cropping system is divided in two different rotations: 130 acres of rotation CCW(SF)M and 115 acres of rotation CCWA. This combination of rotations increases the amount of corn produced from 4218 bushels in Plan 6 to 4988 bushels. Consequently, additional units of poultry can be produced and higher returns obtained.

The number of laying hens produced in this optimum plan is 4456. Returns to labor, capital and management amount to $14,481.

Labor must be hired to satisfy the enterprise requirements during the whole year, except for February and March.

Plan 8

The solution for Plan 8 is similar to the solution in Plan 7, in that the same crop and livestock enterprises enter the program. In Plan 8, the rotation CCW(SF)M is reduced to 60 acres; the remaining 185 acres are occupied by the CCWA rotation. The production of corn is enlarged, allowing production of 4870 hens. Returns are increased to $15,371.

The annual family labor supply is exhausted with the above resource combination. Labor must be hired for each month in further plans producing larger outputs.*

Plan 9

At $16,906 of capital, rotation CCW(SF)W is eliminated from the optimum plan. The total area is cropped with rotation CCWA. The production of corn, the poultry flock, returns and hired labor use are increased at constant rates. No other major changes occur in the plan.

Plans 10, 11 and 12

When more capital than in the previous plans is used, rotation CCCWA, resulting in more corn production, enters the optimum plan. This allows the maximum number of laying hens that can be produced with the available resources other than capital and labor. The poultry enterprise reaches a maximum number of 5646 units. At this point, the optimum amount of corn that can be produced on the farm is fully consumed. No enterprise consuming corn can be enlarged. However, under such conditions there are large amounts of

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*In Situations 1 and 2 the opportunity of hiring labor for each monthly period means that the labor restriction is not a limiting resource for the programmed solutions. Labor becomes practically unlimited. Therefore, in this case, the quantity of labor needed for each plan could be determined endogenously by the program. However, having the data and the matrix already prepared for the computation of other programs, the shortest way to obtain the information was by running these data through the IBM 650 computer. This showed how much labor was left over at each capital level, or when it was necessary to hire additional labor, without laborious desk computing.

unused hay, as is shown in Plan 10. With more capital and labor available, as in Plan 11, feeding two-year-old steers enters the plan. Seventeen steers will consume all the surplus hay. The farmer will receive a return to labor, capital and management of $17,447 with a capital investment of $19,293.

There is still another possibility of increasing returns by means of more capital. Using $19,999, the 17 two-year-old steers could be replaced by 62 yearling steers as was done in Plan 12. Returns to labor, capital and management would be slightly increased and the number of hours of hired labor would be slightly decreased by 57 hours.

Other details of the preceding plans are shown in Table 14 and in Figure 3. The relative contribution of each enterprise to returns is shown in Figure 4 for each capital level.

Effects of different levels of capital with farm size constant and labor supply allowed to vary

Conclusions for this part of the study are similar to those obtained for Situation 1. At the lowest levels of capital, crop rotations are the most profitable activities. As capital increases, livestock enterprises, such as a laying flock, come into the optimum plans and additional labor must be hired to satisfy the labor requirements. More capital investment will produce greater output and higher returns to

Table 14. Situation 2: optimum plans for twelve levels of capital, 245-acre farm

Item	Plan 1	2	3	4	5	6	7	8	9	10	11	12
Level of cap. ($)	700	759	5728	7446	10556	11321	14105	15559	16904	18146	19293	19999
Crop rotations (acre)												
CWA												
CCWA							115	185	245			
CW(SP)M	245											
COM												
COMMM												
CCCCWA												
CCW(SP)M		245	245	245	245	245	130	60				
CCCW(SP)M												
CCCOM												
CCOAAA												
CCCWA										245	245	245
Beef cattle (head)												
Beef cow calves sold												
Beef cow calves fed												42
Yearling steers											17	
Two-year-old steers												

Table 14 (Continued)

Item	Plan											
	1	2	3	4	5	6	7	8	9	10	11	12
Full fed steers												
Hogs (litter) One spring litter												
One fall litter												
Two litters												
Feeder pigs												
Poultry (bird) Laying flock			1770	2353	3386	3636	4454	4870	5212	5646	5646	5646
Corn eq. produced (bu.)	2940	4213	4213	4213	4213	4213	4988	5454	5882	6223	6223	6223
Hay eq. produced (ton)	74	64	64	64	64	64	108	134	159	132	132	132

Table 14 (Continued)

Item	Plan 1	2	3	4	5	6	7	8	9	10	11	12
Unused man-hours (monthly)												
Jan.	474	470	270	204	87	59	0	0	0	0	0	0
Feb.	490	490	316	258	151	132	45	0	0	0	0	0
Mar.	400	414	240	183	81	51	0	0	0	0	0	0
Apr.	331	339	125	55	0	0	0	0	0	0	0	0
May	259	202	14	0	0	0	0	0	0	0	0	0
June	367	371	184	122	13	0	0	0	0	0	0	0
July	390	390	202	41	31	5	0	0	0	0	0	0
Aug.	282	248	61	0	0	0	0	0	0	0	0	0
Sep.	313	299	5	0	0	0	0	0	0	0	0	0
Oct.	326	320	0	0	0	0	0	0	0	0	0	0
Nov.	352	325	14	0	0	0	0	0	0	0	0	0
Dec.	420	424	207	132	0	0	0	0	0	0	0	0
Hired labor hours (monthly)												
Jan.							76	149	217	246	245	244
Feb.									41	77	77	77
Mar.								27	52	89	89	78
Apr.					69	100	247	327	401	422	427	416
May				46	153	184	290	347	399	479	479	469
June						12	100	146	188	227	226	221
July							79	115	141	178	205	197
Aug.					109	136	221	265	305	335	375	369
Sep.				93	271	314	482	576	664	723	722	717
Oct.				109	306	355	483	557	625	703	703	709
Nov.				91	283	330	522	628	726	791	791	786
Dec.						32	144	201	254	292	292	291

Table 14 (Continued)

Item	Plan											
	1	2	3	4	5	6	7	8	9	10	11	12
Used man-hours (annual)	596	698	3362	4244	5826	6216	7520	8338	9013	9562	9631	9574
Corn eq. sold (bu.)	2940	4213	2231	1546	305	0	0	0	0	0	0	0
Unused hay eq. (ton)	74	64	46	40	29	26	63	86	107	76	0	0
Return to labor, capital and management ($)	4140	4351	8549	9906	12154	12707	14481	15375	16186	16932	17447	17528
Limiting resources	Cap. Land	Cap. Land	Cap. Land	Cap. Land	Cap. Land	Cap. Land Corn	Cap. Land Corn	Cap. Land Corn	Cap. Land Corn	Cap. Land Corn	Cap. Land Corn Hay	Cap. Land Corn Hay

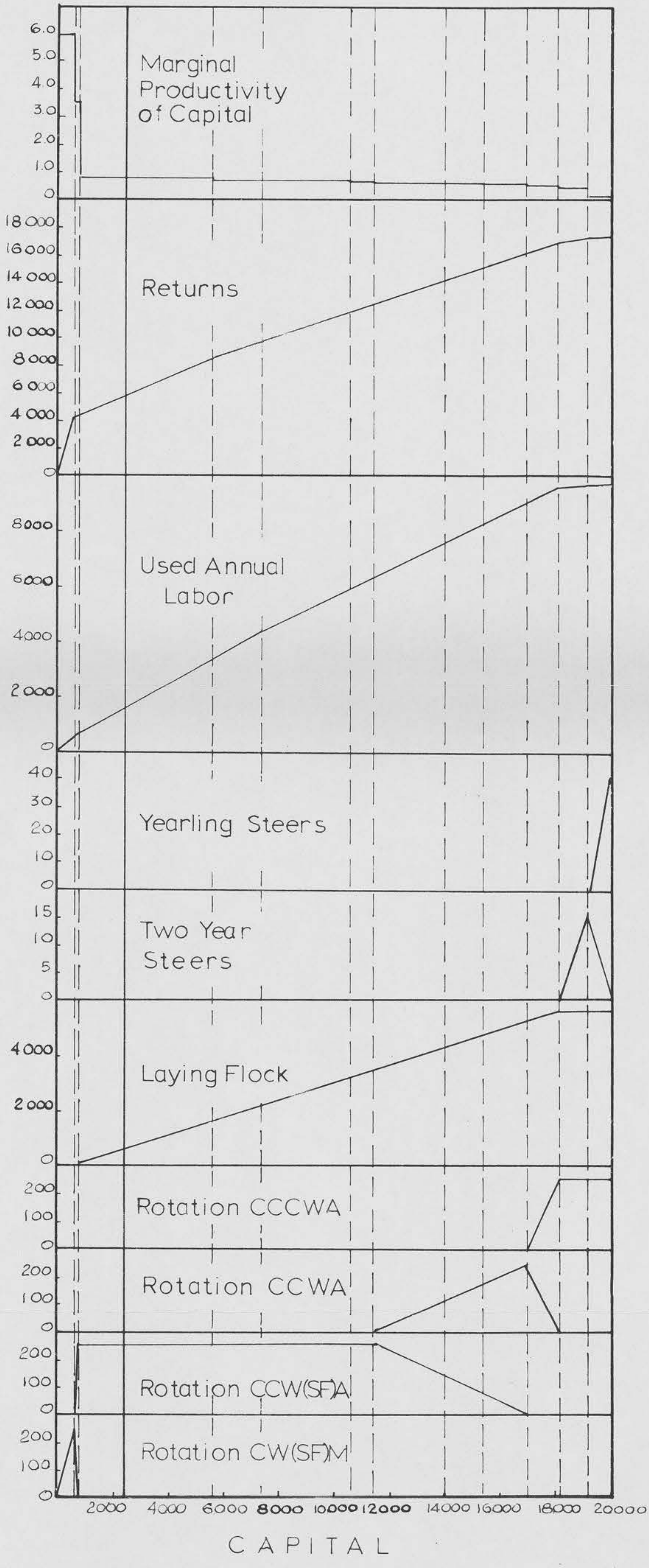

Figure 3. Graphic representation of Situation 2

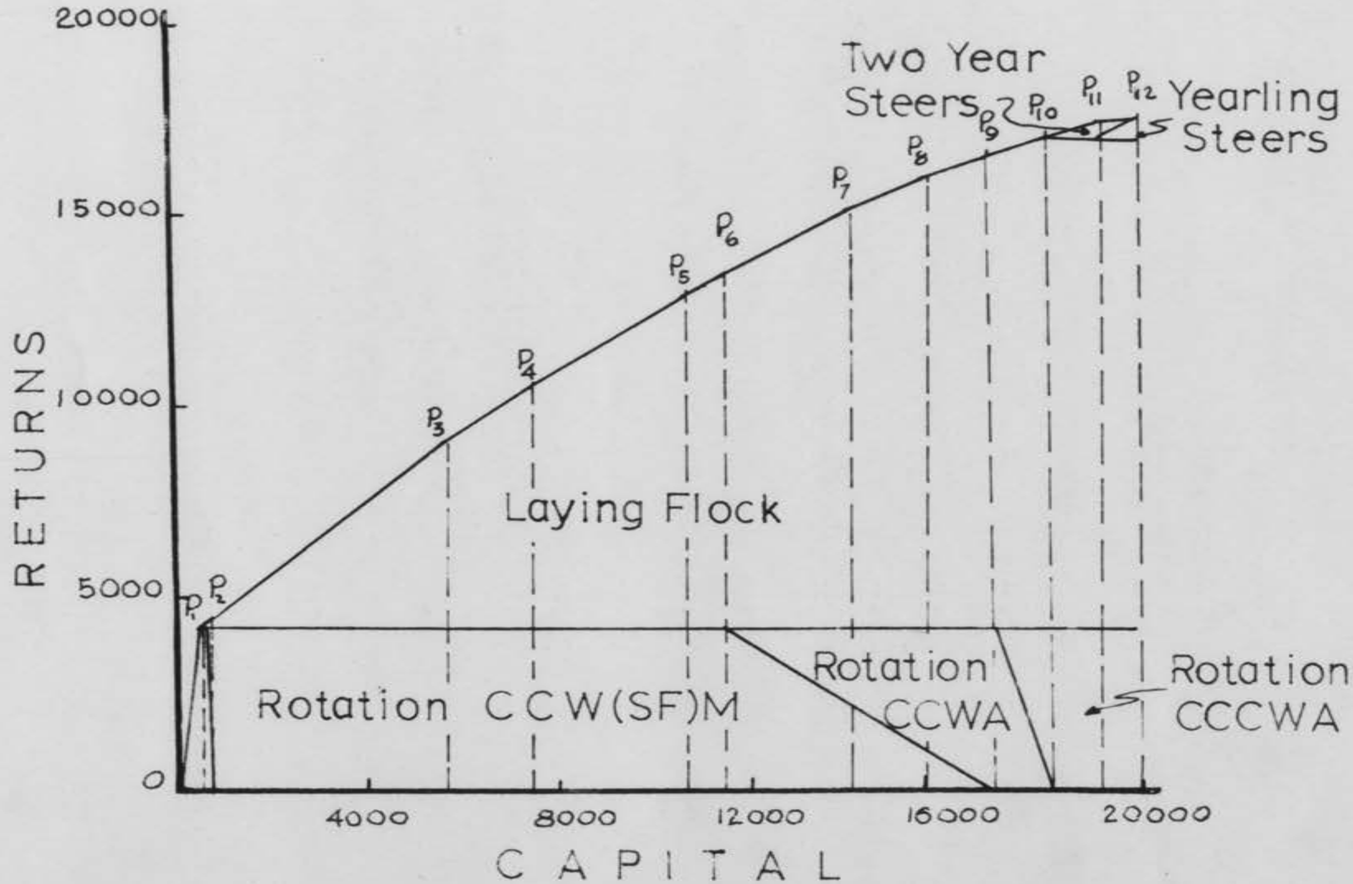

Figure 4. Source of returns, Situation 2

the farmer.

In general, capital can be borrowed advantageously to certain limits. The marginal productivity of each dollar borrowed is greater than the marginal cost or interest rate of 12%, except for Plan 12 as is shown in Table 15.

Although the marginal productivity of capital is greater than its marginal cost until the next to the last plan, the author believes that farmers should think carefully before increasing the scale of operations beyond the levels of capital indicated in Plan 4 or 5.

There are several reasons supporting this hypothesis. In the first place, expansion of the farm business by borrowing such a large amount of funds would subject the operator to great risks, given the conditions prevailing in the local area.* Secondly, the usual relationship between fixed capital and operating capital would be distorted. This would decrease the farmer's equity and the probability of obtaining credit at reasonable interest rates would be very low. Thirdly, with a high capital investment, increasing amounts of labor must be hired to satisfy the requirements of the larger poultry enterprises. The family system of operation will be changed to a commercial laying

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*The so-called "principle of increasing risk" suggests that as a firm expands by use of borrowed capital the chance of loss of its own capital increases (11, p. 543.)

Table 15. Situation 2: marginal productivity of capital

Plan no.	Level of capital	Returns	Marginal productivity
1	700	4,140	5.91
2	759	4,351	3.57
3	5,728	8,549	0.86
4	7,444	9,906	0.78
5	10,556	12,154	0.72
6	11,321	12,707	0.71
7	14,105	14,481	0.63
8	15,559	15,375	0.61
9	16,904	16,186	0.60
10	18,146	16,932	0.60
11	19,293	17,447	0.65
12	19,999	17,528	0.11

flock enterprise. This change would probably become competitive with the family satisfaction, since supervising such an enterprise may not be consistent with the goal of the operator and his family. In addition, a commercial laying flock would demand a degree of knowledge and level of management which can seldom be found in the area.

Therefore, it would seem that the average entrepeneur of the area may have to choose alternative goals besides profit maximization. Because of uncertainty and the reasons described above, the farmer could operate a unit of less than the optimum scale and yet be rational in his decisions.

Comparison of program plans to the system typically followed in the area

In comparing the plans actually followed by operators in the area with about $2450 of capital, with the optimum plan obtained in this study, the following differences can be found:

a. The cropping system CW(SP)M in the present plan is substituted by a rotation producing higher quantities of corn CCW(SP)M.

b. The beef cow-hog system in the actual plan is replaced by 600 laying hens.

c. The introduction of a poultry enterprise and a wider range of crop enterprises increases the present returns from $4801 to $5780 in the optimum plan.

Effects of different levels of capital and different farm size upon enterprise combination and returns

At the lowest levels of capital necessary to cultivate farms of 128 and 245 acres, $365 and $700, respectively, the same rotation CW(SP)M satisfies the maximization objectives. There is a proportional difference in returns when additional land is incorporated into the production process. For example, Plan 1 in Situation 2 uses $335 more operating capital than Plan 1 in Situation 1, but it brings $1977 more returns to the farmer. With this simple enterprise combination it will be highly profitable for the operator of the larger farm to invest capital for cultivating more land.

When capital is used at the second level, Plan 2, rotation CW(SF)M is replaced by rotation CCWA in Situation 1 and by rotation CCW(SF)M in Situation 2. Rotation CCW(SF)M was not considered as an alternative in Situation 1 because, as was mentioned previously, long rotations are not practical on small farms. This means that the operator of the 245-acre farm can choose among a greater number of activities in preparing his optimum plans. The larger farm size and a wider range of activities will bring to the farmer \$1950 of additional returns, while requiring only \$154 more operating capital. The marginal productivity of capital is also higher for Plan 2 in Situation 2, as it can be observed comparing Table 15 with Table 13.

Henceforth returns to labor, capital and management for each level of capital employed are obviously higher in Situation 2, where more land is in cultivation than in Situation 1. However, one important feature must be noted. Starting from Plan 3, where the poultry activity is introduced, the number of laying hens produced by a given amount of capital is comparatively greater in Situation 1 than in Situation 2.

This fact leads to the conclusion that the farmer in Situation 1, because of his labor supply and land restriction, will be better off allocating his capital to the poultry enterprise. A farmer in Situation 2, with more labor and land, should emphasize crop production and keep fewer hens with the same amount of capital. For example, the operator in Situation 1, Plan 4, uses $7658 of capital and 4292 hours of labor to maintain a 2480 bird flock. On the other hand, the farmer in Situation 2, Plan 4, in order to maintain 2358 birds, needs $7444 of capital and 4244 hours of labor In spite of the decrease of $214 in capital the fourth plan returns $1650 more. The reason for these differences is that a 245-acre farm requires more capital and labor to produce a larger amount of crops in relation to the small farm, and therefore fewer resources are available for the poultry activity.

In comparing the 128-acre and the 245-acre farms, the results also show that the latter allows the investment of a greater amount of capital. Production possibilities on the 128-acre farm are fulfilled when $9808 is invested. At this point scarce resources, other than capital, become positive restrictions. On the 245-acre farm the limit to production is reached when $19,999 is invested.

Situation 3: Optimum Plans for 128-Acre Farm With Varying Levels of Capital, With No Hired Labor; 5 Crop and 9 Livestock Activities Included; Laying Flock Excluded From Alternative Activities

In this situation, capital is allowed to vary, but labor is limited to that supplied by the farm family. The poultry enterprise* was excluded from the possible alternatives. This step was taken because in practice there might be considerable reluctance on the part of the farmer to switch to a farm system incorporating a poultry enterprise. Faced with this assumption it will be relevant to know which other enterprise combinations will maximize profits.

Plan 1

At the lowest capital level, $365, the most profitable plan includes only one enterprise: 128 acres of rotation CW(SF)M. No livestock enterprise is allowed to enter the plan at this low level of capital. Therefore 1580 bushels of corn can be sold, and 38.4 tons of hay are at the farmer's disposal.

Returns to labor, capital and management for Plan 1 are $2163. Only 280 hours of direct labor are used, out of an annual supply of 4560 man hours.

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*In Situation 3 and following Situations 4, 5, 6 and 7 the poultry enterprise was no longer included as an alternative. According to the budgets the relationship between the net price of one unit of laying flock and its capital coefficient is comparatively more favorable than are the relationships between the prices of hog and beef cattle enterprises and their capital coefficients. Less capital and feed are used by the laying flock enterprise in obtaining the same basic net price. Under these circumstances the optimum plan would always include the laying flock as the predominant activity.

Plan 2

As the capital level is increased to $605, rotation CCWA replaces rotation CW(SF)M on all 128 acres. Alfalfa is grown instead of meadow and the sunflower seed crop is replaced by corn, resulting in increased corn and hay production. No livestock enterprises are included in the plan.

The production of corn increases to 3070 bushels and the production of hay equivalent to 83.2 tons.

Returns to labor, capital and management are $2407 for this plan. Labor increases from 280 hours per year previously to 543 hours per year in the present plan.

Plan 3

Investment of $4088 of operating capital permits the introduction of a livestock enterprise. The optimum plan includes the same 128 acres of rotation CCWA, and 15 litters from a 2 litter hog system.* The hog activity utilizes all the corn produced, 3070 bushels, leaving nothing to be sold. Hence, corn becomes a positive limiting resource to the production process.

Labor use increases from 543 hours to 1242 hours per year. Returns to labor, capital and management are $4902.

*This means 15 litters twice a year.

Plan 4

In spite of the restriction imposed by the amount of corn produced in the previous plan, returns can still be increased with more capital.

With $4702 of capital, crop activity remains the same, but the 15 litters of hogs are replaced by 274 feeder pigs. With the inclusion of the feeder pig enterprise, the corn produced is also totally consumed on the farm and therefore corn again becomes a limiting resource. The quantity of hay increases to 74.9 tons.

Labor used declines from 1242 hours in the former plan to 1093 hours, because of the entry of feeder pigs into the program. Nevertheless, returns to capital, labor and management increase to $5242.

Plan 5

An appreciable amount of hay was left unused in the foregoing plans. With capital increased to $5829, it is possible to feed 17 two-year-old steers in addition to feeding 276 pigs and raising 128 acres of the CCWA rotation.

With the introduction of a hay consuming beef cattle enterprise, corn and hay are fully utilized by the livestock activities.

Labor requirements increase to 1136 hours. Returns to labor, capital and management increase substantially to $5772.

Plan 6

Notwithstanding that capital, land, corn and hay were completely employed in Plan 5 and were effective restrictions, it is still possible to change the enterprise combination and increase income if more capital is applied to the production process.

At the $6507 capital level, 41 yearling steers replace 17 two-year-old steers. The crop rotation and hog enterprise remain the same. Corn and hay utilization is also maximized as it was in Plan 5. Returns to labor, capital and management are $5850 or $78 higher than in the previous plan. Annual labor use remains almost identical.

No plans can be obtained beyond Plan 6. At this point scarce resources other than capital place positive restrictions on the production process.

Effects of different levels of capital with farm size and labor supply constant

At the lowest levels of capital ($365 and $605) the most profitable programs include only crop enterprises.

Higher levels of capital investment, $4088, will diversify production by including livestock enterprises. If capital is increased further, to $4702 or more and is partly in a beef enterprise, higher profits result.

However, if capital must be borrowed, the marginal productivity of capital should be taken into consideration.

Table 16. Situation 3: optimum plans for six levels of capital, 128-acre farm

Item	Plan 1	2	3	4	5	6
Level of capital ($)	365	605	4088	4702	5829	6527
Crop rotations (acre)						
CWA						
CCWA		128	128	128	128	128
CW(SF)M	128					
COM						
COMMM						
Beef cattle (head)						
Beef cow calves sold						
Beef cow calves fed						
Yearling steers						41
Two-year-old steers					17	
Full fed steers						
Hogs (litter)						
One spring litter						
One fall litter						
Two litters			15			
Feeder pigs (head)				274	274	274
Corn eq. produced (bu.)	1530	3070	3070	3070	3070	3070
Hay eq. produced (ton)	38.4	83.2	83.2	83.2	83.2	83.2

Table 16 (Continued)

Item	Plan 1	2	3	4	5	6
Unused manhours (monthly)						
January	381	331	280	331	328	327
February	390	382	306	382	376	377
March	334	367	302	367	363	366
April	350	299	248	190	187	190
May	317	264	204	154	150	154
June	378	378	334	268	265	268
July	390	390	335	280	276	280
August	334	318	222	208	204	208
September	340	287	215	287	283	287
October	347	347	299	347	365	335
November	365	300	260	300	295	296
December	354	354	313	353	352	346
Used manhours (annual)	280	543	1242	1093	1136	1126
Corn eq. sold (bu.)	1530	3070	0	0	0	0
Unused hay eq. (ton)	38.4	83.2	62.0	74.9	0	0
Return to labor, capital and management ($)	2163	2407	4902	5252	5772	5850
Limiting resources	Cap. Land	Cap. Land	Cap. Land Corn	Cap. Land Corn	Cap. Land Corn Hay	Cap. Land Corn Hay

The marginal productivity of capital will be greater than its marginal cost only to the extent of Plan 5 as is shown in Table 17.

Table 17. Situation 3: marginal productivity of capital

Plan no.	Level of capital	Returns	Marginal productivity
1	365	2163	5.92
2	605	2407	1.02
3	4088	4902	0.71
4	4702	5252	0.57
5	5829	5772	0.46
6	6527	5850	0.11

At an annual rate of interest of 12%, borrowing funds for investments that will return only 11 cents for each dollar invested would not be economical.

Annual family labor utilization is greatest under Plan 3 with $4088 of capital when 27% of the total labor supply is used. Therefore, the operator's labor will be sufficient to satisfy the monthly requirements for all plans. The investment of more capital does not necessarily lead to fuller utilization of the total labor supply.

The solution for Situation 3 is presented graphically in Figure 5. Rotation CW(SP)M comes in and then drops out of

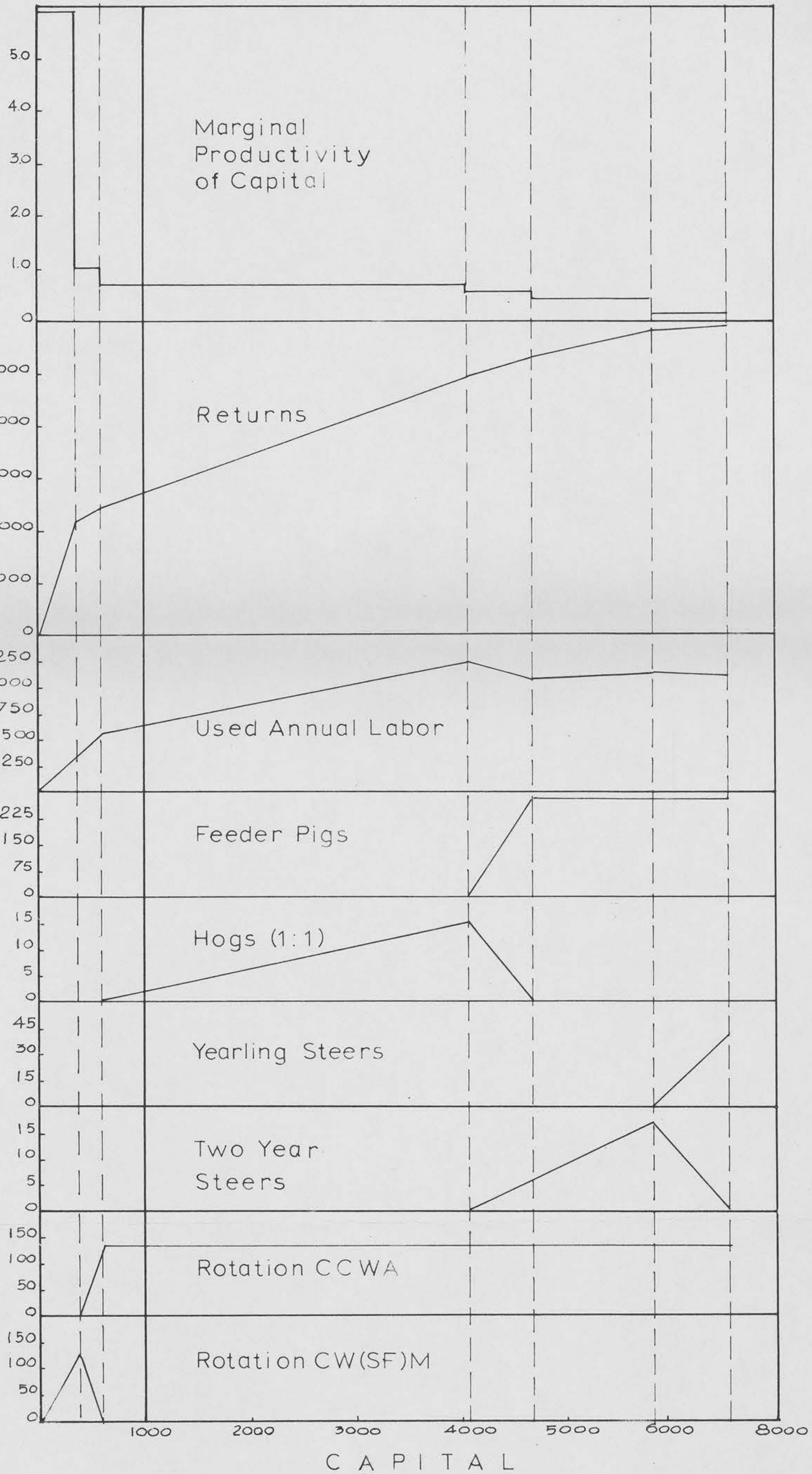

Figure 5. Graphic representation of Situation 3

the optimum plan because it competes with rotation CCWA at higher capital levels.

Feeding two-year-old and yearling steers, feeding pigs and raising hogs under a two-litter system are supplementary with rotation CCWA. The two-litter hog system and feeder pigs compete between the $4088 and $4702 levels. The two cattle feeding enterprises compete for the use of resources between the $5829 and $6527 capital levels.

The relative importance of each enterprise from the standpoint of returns at each capital level of Situation 3 are shown in Figure 6. At the lowest levels of capital, crop rotations are the main source of returns. From the medium range of capital and upwards, the crop rotation and hog enterprises contribute the largest share of returns.

Comparison of program plans to the system typically followed in the area

In comparing the optimum plan using $1000 of capital with the plan followed by the typical operator of a 128-acre farm in the area with a similar investment, the following differences can be noticed:

a) The rotation system, CCW(SF)A typical of the area is replaced by a more intensive corn system, CCWA.

b) The beef cattle-hog combination found in the area is replaced by two units of the two-litter hog system in the optimum plan.

c) Because of the changes in crop and livestock activities indicated by the programming process, returns from the

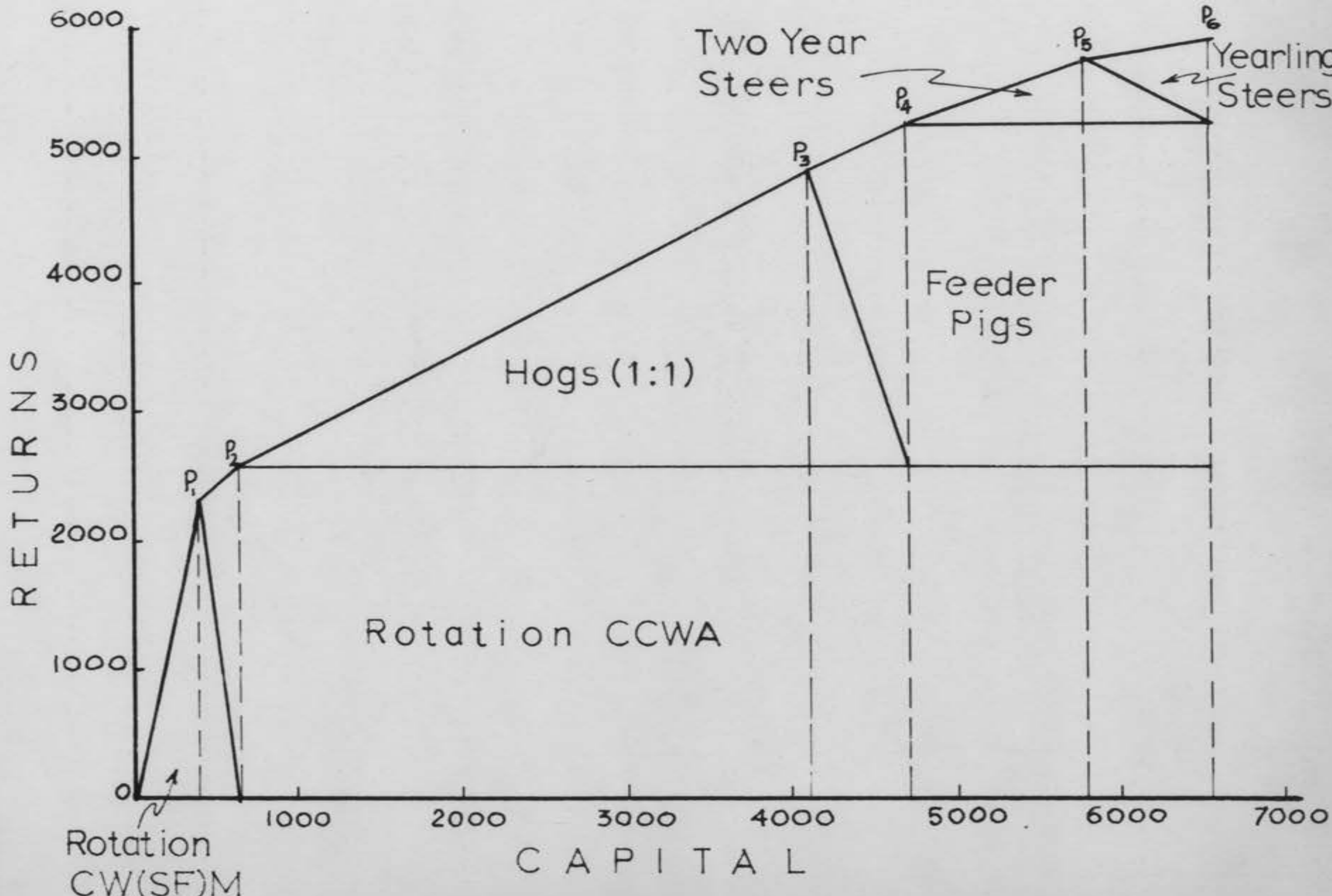

Figure 6. Source of returns, Situation 3

optimum plan are 7% greater than with the existing farm organization.

Situation 4: Optimum Plans for 245-Acre Farm, With Varying Levels of Capital, No Hired Labor, Including 11 Rotations and 9 Livestock Activities; Laying Flock Excluded

In this situation, six crop rotations in addition to the five considered in Situation 3 were introduced, providing more flexibility in the choice of a farming system. The livestock activities are the same as in Situation 3.

Plan 1

The lowest capital level is $700 as it was in Plan 1, Situation 2. The most profitable plan at the $700 capital level, as in Plan 1, Situation 1, 2 and 3 is 245 acres of rotation CW(SF)M. No livestock enterprise enters the plan.

Returns to labor, capital and management are $4140. Only 598 hours of labor out of the 5000 hour labor supply are used.

Plan 2

When capital increases to $759, a change in rotation occurs: rotation CCW(SF)M replaces rotation CW(SF)M on all 245 acres. Returns to labor, capital and management are increased by $211 to $4351.

Plan 3

At a capital level of $2450 the same 245 acres of rotation CCW(SF)M are maintained in this optimum plan. Ten litters of a 2-litter hog system also enter the plan at this point. The hog activity consumes 1490 bushels of corn, leaving 2720 bushels to be sold, as well as 10.3 tons of hay.

Returns to labor, capital and management increase from $4351 to $5562 and the labor used from 688 hours to 1023 hours annually.

Plan 4

When capital increases to $5540 the main departure from Plan 3 is that the 2-litter hog enterprise increases from 10 litters to 21 litters. At this level hogs give the highest returns per dollar invested. With this quantity of livestock, all the corn is consumed and corn becomes a restriction. Thirty-four and a half tons of hay remain unused.

Returns to labor, capital and management are $7775 and the labor used is 1641 hours per year.

Plan 5

At a $7829 level of capital rotation CCW(SF)M is replaced by rotation CCWA on all 245 acres, increasing the amount of corn produced from 4210 bushels to 5874 bushels. However, more corn is needed to feed the additional litters of hogs which can be raised with more capital and the grain is completely consumed. Alfalfa is used in place of permanent pasture. The two-litter hogs increase from 21 litters in the previous plan to 29 litters. The hay available increases to 118.6 tons because rotation CCWA produces higher amounts of forage than rotation CCW(SF)M included in Plan 4, and a high forage consuming activity, like beef cattle, is not permitted to enter the plan at the level of capital indicated in this plan.

Returns to labor, capital and management are $9386 and the labor used increases substantially from 1641 hours to 2430 annual hours. Corn production is the additional restriction at this level of capital.

Plan 6

Investment of $8298 of capital permits a plan which includes 10 acres of rotation CCWA and 235 acres of rotation CCCWA. This change is due to the fact that more corn is needed for two additional units of the 2-litter hog system, which now total 31 units.

However, this plan should not be recommended. Ten acres of rotation CCWA imply very impractical field sizes, and this rotation could be dropped without significantly affecting profits.

The hog enterprise utilizes all the corn produced. Less hay equivalent is left over than in the former plan, principally because less hay is produced with rotation CCCWA.

This plan produces a return of \$9679 and utilizes approximately 50% of the total annual labor supply. However, it must be noted that May labor also becomes an effective restriction together with corn.

Plan 7

As capital is increased to \$9645, rotation CCWA is increased to 35 acres, and rotation CCCWA is reduced to 210 acres. Corn and hay production remain at almost the same level as in Plan 6. But 21 two-year-old steers enter the plan simultaneously with the 31 litters produced from the 2-litter hog system, as in the former plan.

With the above livestock enterprise combination, all hay and corn produced are utilized. Both feeds become restrictions in addition to capital and land. The limiting May labor causes a reduction in rotation CCCWA which, because of its higher percentage of corn, needs more labor during May than rotation CCWA. The labor peak is due to corn picking in May.

The plan becomes more diversified, with less risk, in respect to the former plans 1-6, and produces \$10,294 of returns. Labor is used to the extent of 2560 hours annually.

Plan 8

At the next to the highest capital level considered, \$10,216, the crop system, because of the labor restriction indicated in the previous plan, reverts to 245 acres of rotation CCWA. The change increases the production of alfalfa hay and reduces the production of corn to 5875 bushels. Consequently, with enough capital, resources could be allocated to feeding cattle and hogs, rather than farrowing and raising hogs. The increased capital and hay and the reduction of the May labor requirement with the CCWA rotation allow the farmer to purchase and feed out 29 two-year-old steers. The size of the two-litter hog system is reduced from 31 to 18 litters, but with increased capital and more May labor available, 205 pigs can be fed out with the remaining corn and hay. The combined effect of the increased livestock program and the reduced corn production is the full utilization of the feed produced on the farm.

Labor use is reduced from 2560 to 2389 hours per year and returns increase from $10,294 to $10,538.

Plan 9

At the highest level of capital used in the program, $11,526, the rotation system and feed production remain the same as in the former plan. The two-year-old steer feeding activity goes out of the optimum plan, mainly because of the May labor restriction. A new enterprise, 72 yearling steers, enters the optimum plan in its place. This activity does not require any May labor. The 2-litter hog system is reduced to 16 litters and the units of feeder pigs are increased to 239.

The 2-litter hog system is reduced because its May labor requirement is much greater than the requirements for feeding cattle during the same month. To maximize profits, the 2-litter system must be reduced so May labor can be allocated to the cattle enterprise.

The diversified livestock system specified in Plan 9 will use all the corn and hay produced and result in maximum returns to labor, capital and management of $10,727. However, the utilization of labor during the year is not increased, but decreased with respect to Plans 5, 6, 7 and 8.

Details of each plan for this situation are given in Table 18.

Effects of different levels of capital with farm size and labor supply constant

As in Situations 1, 2 and 3, the amount of capital used in the production process has a remarkable influence on the enterprise combination and on the number of units in the final plans.

At the lowest capital levels (Plans 1 and 2) the farmer will obtain more returns with crop enterprises alone; therefore all resources are invested in crops. Capital is so limited that no livestock enterprises can be produced conveniently.

Table 18. Situation 4: optimum plans for nine levels of capital, 245-acre farm

Item	Plan 1	2	3	4	5	6	7	8	9
Level of capital ($)	700	759	2450	5540	7829	8298	9645	10216	11526
Crop rotations (acre)									
CWA									
CCWA					245	10	35	245	245
CW(SP)M	245								
COM									
COMMM									
CCCCWA									
CCW(SP)M		245	245	245					
CCCW(SP)M									
CCCOM									
CCOAAA									
CCCWA						235	210		
Beef cattle (head)									
Beef cow calves sold									
Beef cow calves fed									
Yearling steers									72
Two-year-old steers							21	29	
Full fed steers									
Hogs (litter)									
One spring litter									
One fall litter									
Two litters			10	21	29	31	31	18	16
Feeder pigs (head)								205	239
Corn eq. produced (bu.)	2940	4210	4210	4210	5875	6300	6243	5875	5875
Hay eq. produced (ton)	74	64	64	64	159	135	135	159	159

Table 18 (Continued)

Item	Plan								
	1	2	3	4	5	6	7	8	9
Unused manhours (monthly)									
January	474	470	446	401	280	288	283	313	317
February	490	490	453	386	330	322	315	376	388
March	400	414	383	326	340	333	329	383	396
April	331	339	314	269	138	156	151	88	86
May	259	202	173	120	43	0	0	0	0
June	367	371	350	311	282	281	276	227	225
July	390	390	363	315	286	278	274	238	237
August	282	248	202	118	69	30	29	52	56
September	313	299	265	201	74	71	66	121	136
October	324	320	291	255	235	223	222	268	256
November	352	335	315	279	150	152	148	175	178
December	420	434	415	378	343	350	347	370	365
Used manhours (annual)	598	688	1023	1641	2430	2516	2560	2389	2360
Corn eq. sold (bu.)	2940	4210	2720	0	0	0	0	0	0
Unused hay eq. (ton)	74	64	53	35	119	90	0	0	0
Return to labor, capital and management ($)	4140	4351	5562	7775	9386	9679	10294	10538	10727
Limiting resources	Cap. Land	Cap. Land	Cap. Land	Cap. Land Corn	Cap. Land Corn	Cap. Land Labor Corn	Cap. Land Labor Corn Hay	Cap. Land Labor Corn Hay	Cap. Land Labor Corn Hay

As capital increases, the farming system becomes more diversified and several livestock activities enter the plans at each level of capital. Hay production increases; but the hay is fully utilized by the beef enterprises included in the plans at high capital levels. Therefore, returns are higher when part of the operating capital is invested in beef enterprises rather than in hogs.

The marginal productivity of capital is still greater than the prevailing interest rate up to the last plan, where production is definitely limited by resources other than capital. Table 19 shows the marginal productivity of capital for each level of capital investment.

Table 19. Situation 4: marginal productivity of capital

Plan no.	Level of capital	Returns	Marginal productivity
1	700	4,140	5.91
2	759	4,351	3.58
3	2,450	5,562	0.71
4	5,540	7,775	0.71
5	7,829	9,386	0.70
6	8,298	9,679	0.62
7	9,645	10,294	0.65
8	10,216	10,538	0.43
9	11,526	10,727	0.14

Labor is not used beyond 50% of the total supply even in the high capital plans. May labor becomes a restriction in Plan 6 at the $8298 level of capital. However, different and more profitable plans are possible because May labor is reallocated among other enterprises that use less May labor.

One member of the family could accept off-farm employment without affecting the farming operation in most of the plans, at least during six months of the year. Conceivably one man equivalent could leave the farm in Plans 1 and 2 without changing the nature of the production process.

Situation 4 is graphically represented in Figure 7. The contribution of each enterprise to returns is shown in Figure 8. In this situation the hog enterprises contribute greatly to returns at medium and high levels of capital. At low levels returns come mainly from the crop rotation.

<u>Comparison of program plans to the system typically followed in the area</u>

In comparing the optimum plan using $2450 of capital with plans typically followed in the area by operators with a similar amount of capital, the following differences are found:

a. The crop system CW(SF)M typically used is replaced by a rotation producing higher quantities of corn, CCW(SF)M.

b. More emphasis is placed on hog production and less on beef raising

c. Because of the changes introduced in the crop and

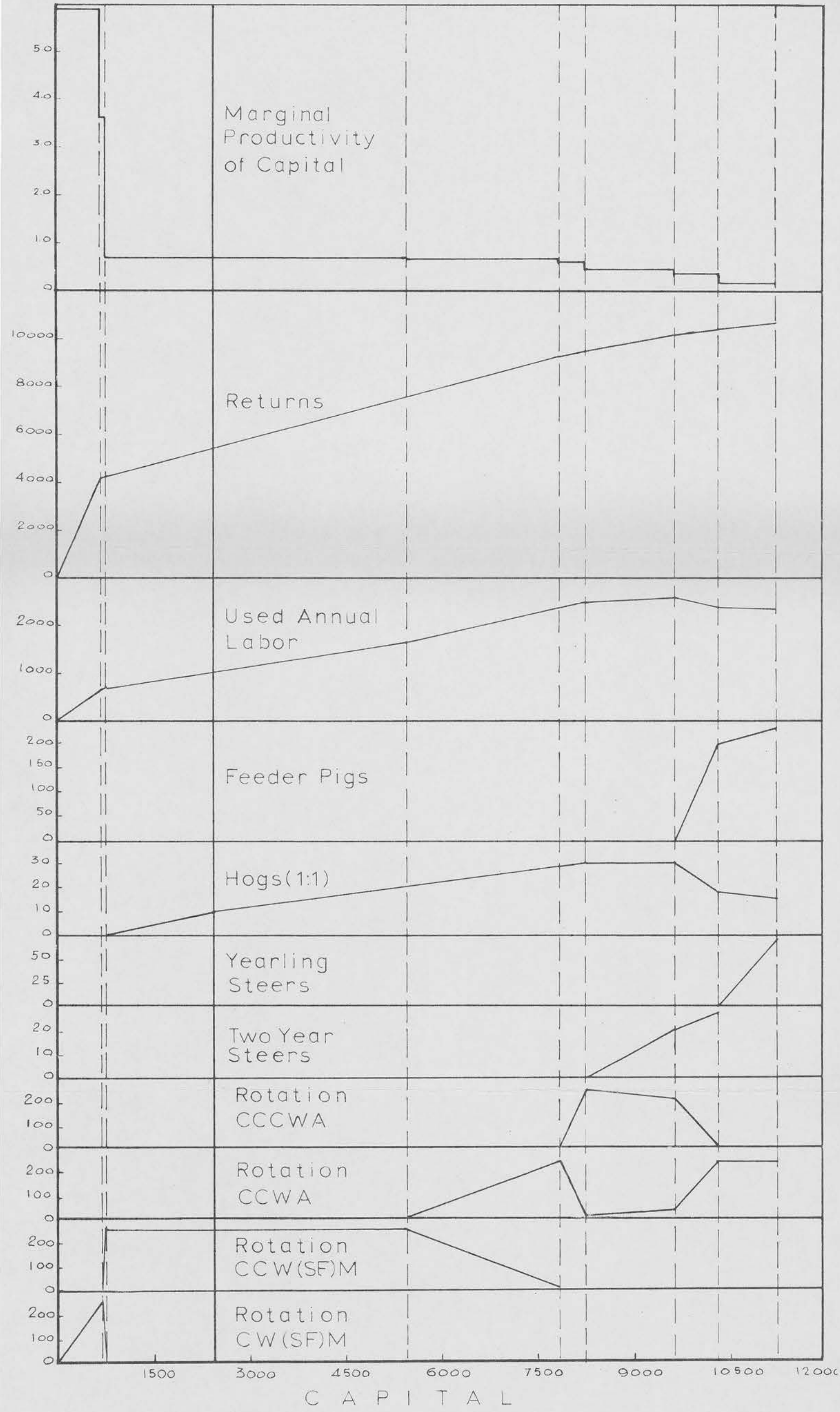

Figure 7. Graphic representation of Situation 4

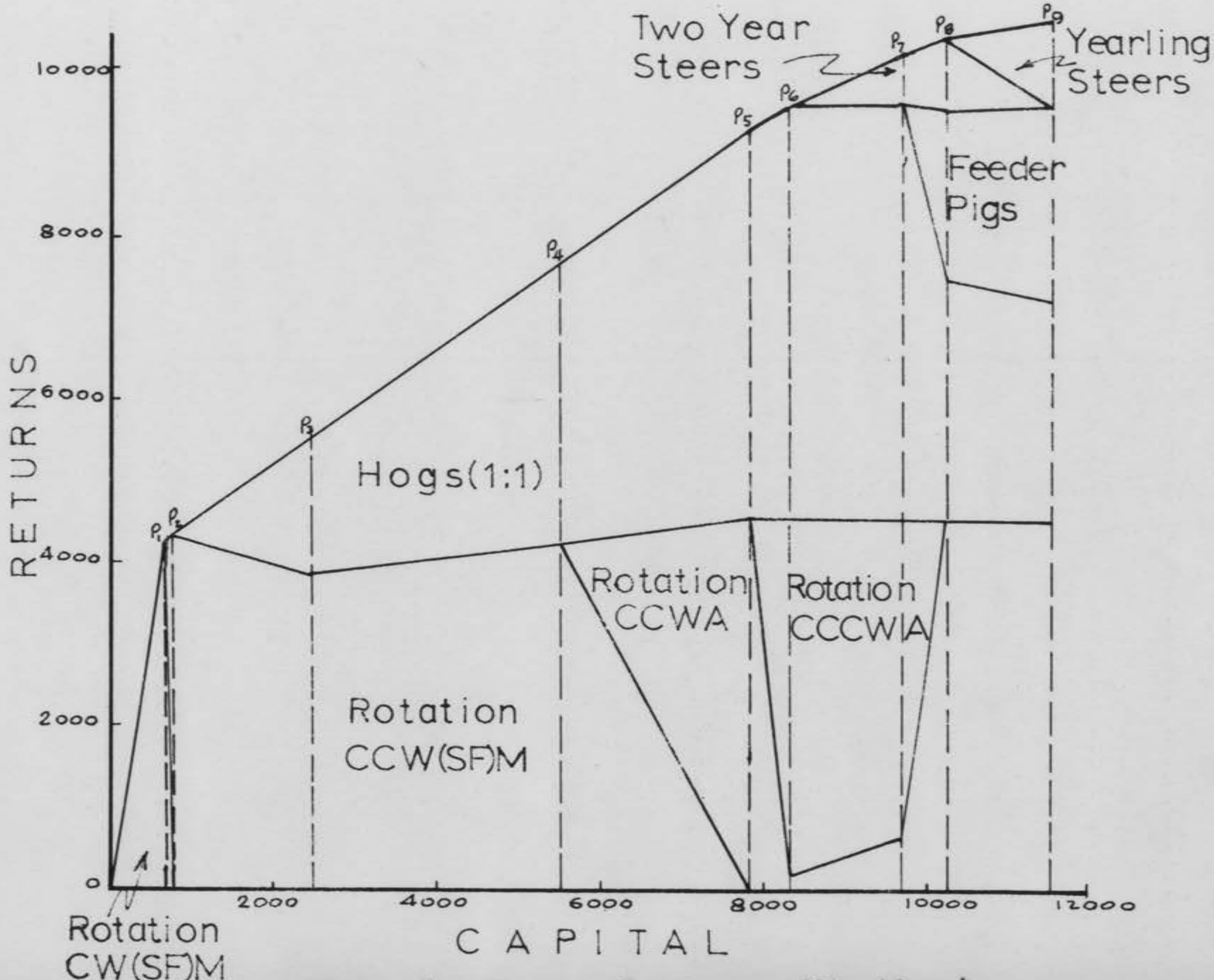

Figure 8. Source of returns, Situation 4

livestock systems, returns are increased from $4801 in the present plan followed by the farmer to $5562 in the programmed plan.

<u>Effects of different levels of capital and farm size upon enterprise combination and returns</u>

When very low levels of capital are used (Plan 1 in Situation 3, 128-acre farm, and Situation 4, 245-acre farm) the same type of rotation CW(SF)H produces the maximum returns regardless of farm size and amount of capital. No difference results because no livestock activity is produced at this level and labor is not yet a restriction. However, the additional 117 acres of land in crop adds $1997 to returns, but only $335 to the amount of capital required.

Returns to labor, capital and management are higher for Situation 4, where more land is available. A comparison of Plan 3 in Situation 4 and Plan 3 in Situation 3 will show that the 245-acre farm requires $1638 less capital but brings a $660 greater return. In this case the 245-acre farm requires less capital because plans are maximized with fewer units of livestock, such as 10 two-litter hogs instead of 15. The amount of funds required to raise one unit of livestock is generally much greater than the amount required to cultivate one unit of crop rotation, as is shown by the capital coefficients indicated on Table 10. Consequently, by decreasing the size of the livestock enterprises, more capital remains available to satisfy resource requirements for cropping the 245-acre farm.

Likewise, the addition of more land allows the application of greater amounts of operating capital to the production process. Eleven thousand five hundred and twenty-six dollars of capital can be applied on the 245-acre farm and $10,727 of returns can be obtained before other scarce resources, such as corn and hay, are fully utilized and become limiting factors. In Situation 3 of the 128-acre farm, the scarce resources under the assumed conditions are exhausted when only $6527 are utilized, bringing returns of $5850.

On the other hand, the optimum plans with the high levels of capital for the 245-acre farm could be more advantageous because of greater diversification.

The farm family labor is also more intensively employed on the 245-acre farm.

Situation 5: Optimum Plans for 128-Acre Farm, Including 5 Rotations, 5 Beef Cattle Enterprises and With Hog and Poultry Raising and Labor Hiring Activities Excluded

Plans outlined in Situations 3 and 4 include hog enterprises for both the 128-acre and the 245-acre sizes.

In Situations 5 and 6, although farms of the same sizes are considered and capital is always allowed to vary, hog enterprises were dropped as possible alternatives. The reason for doing this was to find what beef cattle alternatives would be added to the optimum plans if hog production did not compete for scarce resources. Labor can not be hired in this situation either.

Plans 1 and 2

Since no modifications were made in the input-output coefficients in relation to those used in the previous situations, Plans 1 and 2, at $365 and $605 of capital level, are similar to those optimum plans obtained in Situations 1 and 3.

Plan 3

At $1850 level of capital, rotation CCWA is used in the optimum plan. Nineteen two-year-old steers enter the program, consuming all the hay produced (83.1 tons). Hay becomes a restriction together with capital and land. No corn is consumed by the two-year-old steer enterprise, and the total amount of corn produced, 3070 bushels, can be marketed. Only 587 annual hours of labor are used out of the 4560 annual supply.

Returns for this plan are $2407.

Plan 4

With more operating capital available, $4726, the same rotation, CCWA, still remains in the optimum plan. Two-year-old steers are replaced by 54 full fed steers which consume 1820 bushels of corn and all of the hay equivalent which is produced.*

Labor is not restricting during any month in this plan. Only 620 hours of labor are used out of the 4560 annual supply.

Returns are increased from $2407 in the previous plan to $3630.

Plan 5

The highest level of capital that can be utilized, given the restrictions for this situation, is $5998. At this level, 128 acres of rotation CWA enter the optimum plan in place of 128 of rotation CCWA. Because of this, total corn production decreases from 3070 bushels to 2215 bushels. At the same time, hay production increases from 83.1 to 106.5 tons. The percentage of the hay crop is much greater in the new rotation, allowing the expansion of the steer feeding enterprise to 70 head. All hay produced and 1045 bushels of corn are consumed by the beef enterprise.

Only 651 hours or about 7% of the total labor supply is utilized in this last plan, which is definitively limited by hay production.

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*It should be remembered that between Plan 3 with $1850 level of capital and Plan 4 with $4726, or between any other levels of capital, there are several possible capital levels which can allow different feasible plans. By application of the simple procedure described in the footnote on pp. 44-45, the optimum plan which will result from any desired level of capital can be found.

Details of the preceding 5 plans are given on Table 20.

<u>Effects of different levels of capital with farm size and labor supply constant</u>

With no hog activities permitted, the possibilities for diversifying production and of using large amounts of capital are restricted. The hay produced is consumed at low capital levels and becomes a positive restriction before other resources can be fully utilized.

The low capital plans 1 and 2 bring higher returns when capital is invested in crop rather than livestock production.

As capital increases, livestock enterprises enter the optimum plan. For example, with a capital level of $1850, as in Plan 3, a two-year-old steer feeding activity comes into the program, using all the hay produced by the 128 acres of rotation CCWA. With more capital the two-year-old steers are replaced by full fed steers and the corn raised is partially fed. At the highest level of capital (Plan 5) the full fed activity is increased and rotation CCWA shifts to CWA. The quantity of hay produced is increased and corn is decreased.

In Plan 5 the marginal productivity of capital is only 3%, as shown in Table 21. Since the interest rate (which equals marginal cost) on borrowed capital is 12%, borrowing funds for farm operation at this high capital level would not be profitable.

Table 20. Situation 5: optimum plans for five levels of capital, 128-acre farm

Item	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
Level of capital ($)	365	604	1850	4726	5898
Crop rotations (acre)					
CWA					128
CCWA		128	128	128	
CW(SF)M	128				
COM					
COMMM					
Beef cattle (head)					
Beef cow calves sold					
Beef cow calves fed					
Yearling steers					
Two-year-old steers			19		
Full fed steers				54	70
Corn eq. produced (bu.)	1530	3070	3070	3070	2215
Hay eq. produced (ton)	38.4	83.1	83.1	83.1	106.5
Unused manhours (monthly)					
January	381	331	328	331	317
February	390	382	375	382	379
March	333	367	363	357	353
April	350	300	296	294	269
May	317	264	260	254	284
June	378	378	374	363	354

Table 20 (Continued)

Item	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
Unused manhours (monthly) (continued)					
July	390	390	386	375	370
August	333	318	314	302	322
September	340	287	283	281	274
October	347	347	345	347	352
November	365	300	297	300	293
December	353	354	352	354	342
Used manhours (annual)	283	542	587	620	651
Corn eq. sold (bu.)	1530	3070	3070	2250	1170
Unused hay eq. (ton)	38.4	83.1	0	0	0
Return to labor, capital and management ($)	2163	2407	2985	3630	3693
Limiting resources	Cap. Land	Cap. Land	Cap. Land Hay	Cap. Land Hay	Cap. Land Hay

Table 21. Situation 5: marginal productivity of capital

Plan no.	Level of capital	Returns	Marginal productivity
1	365	2,163	5.90
2	604	2,407	0.98
3	1,850	2,945	0.43
4	4,726	3,630	0.24
5	5,898	3,693	0.03

Since no more than 15% of the total labor supply is used in any one of the plans which exclude hogs and poultry, one man equivalent could leave the farm without interfering with the production process.

Situation 5 is graphically represented in Figure 9. Rotation CW(SF)M is competitive with rotation CCWA at low levels of capital. Rotation CWA competes with CCWA in the last stages and is complementary with full fed steers at high levels of capital. A graphic presentation of the relative contribution of enterprises to returns for each capital level is shown in Figure 10.

Comparison of program plans to systems typically followed in the area

In comparing plans typical of the area with the optimum plan obtained from programming for similar capital levels the

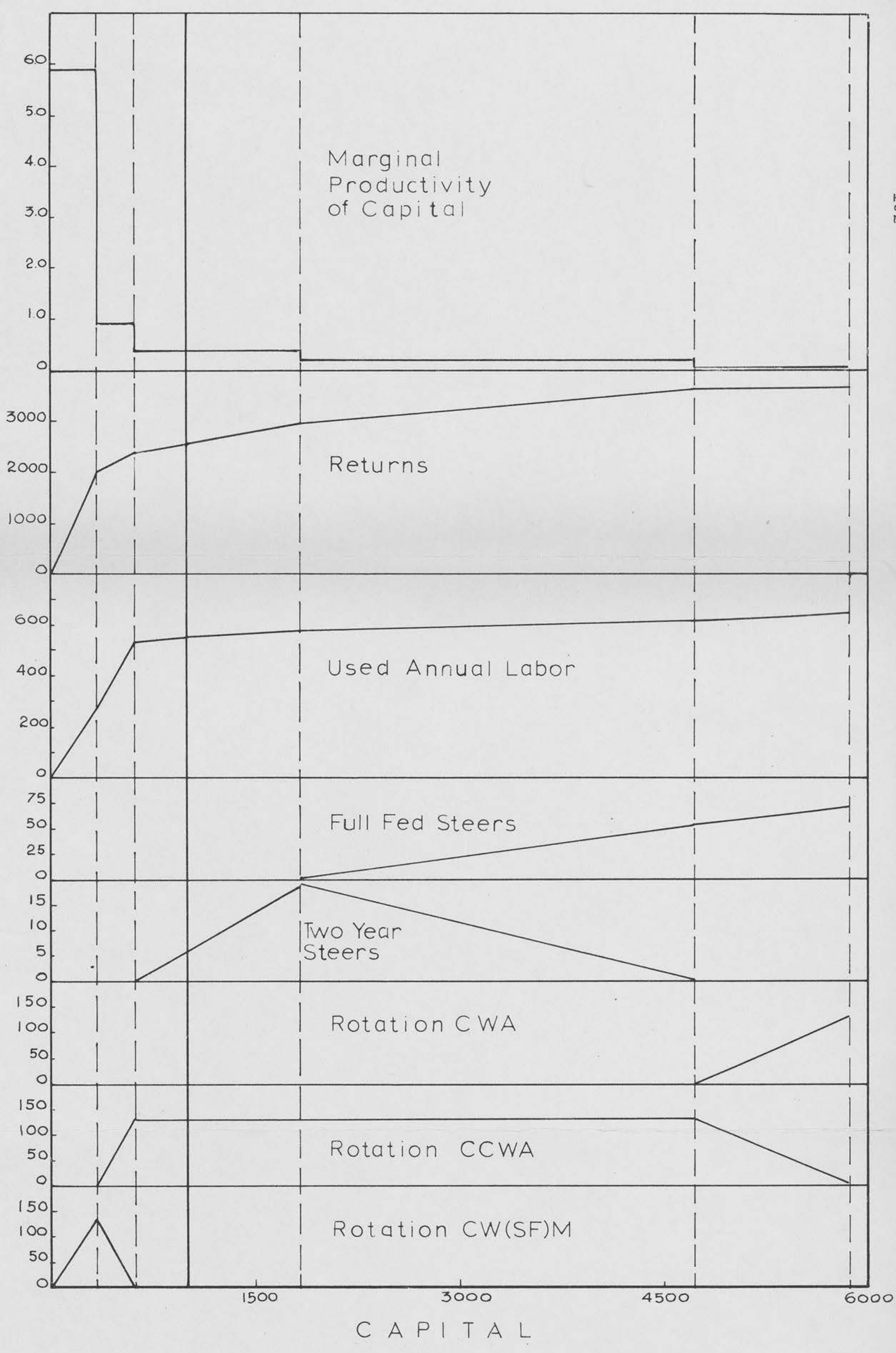

Figure 9. Graphic representation of Situation 5

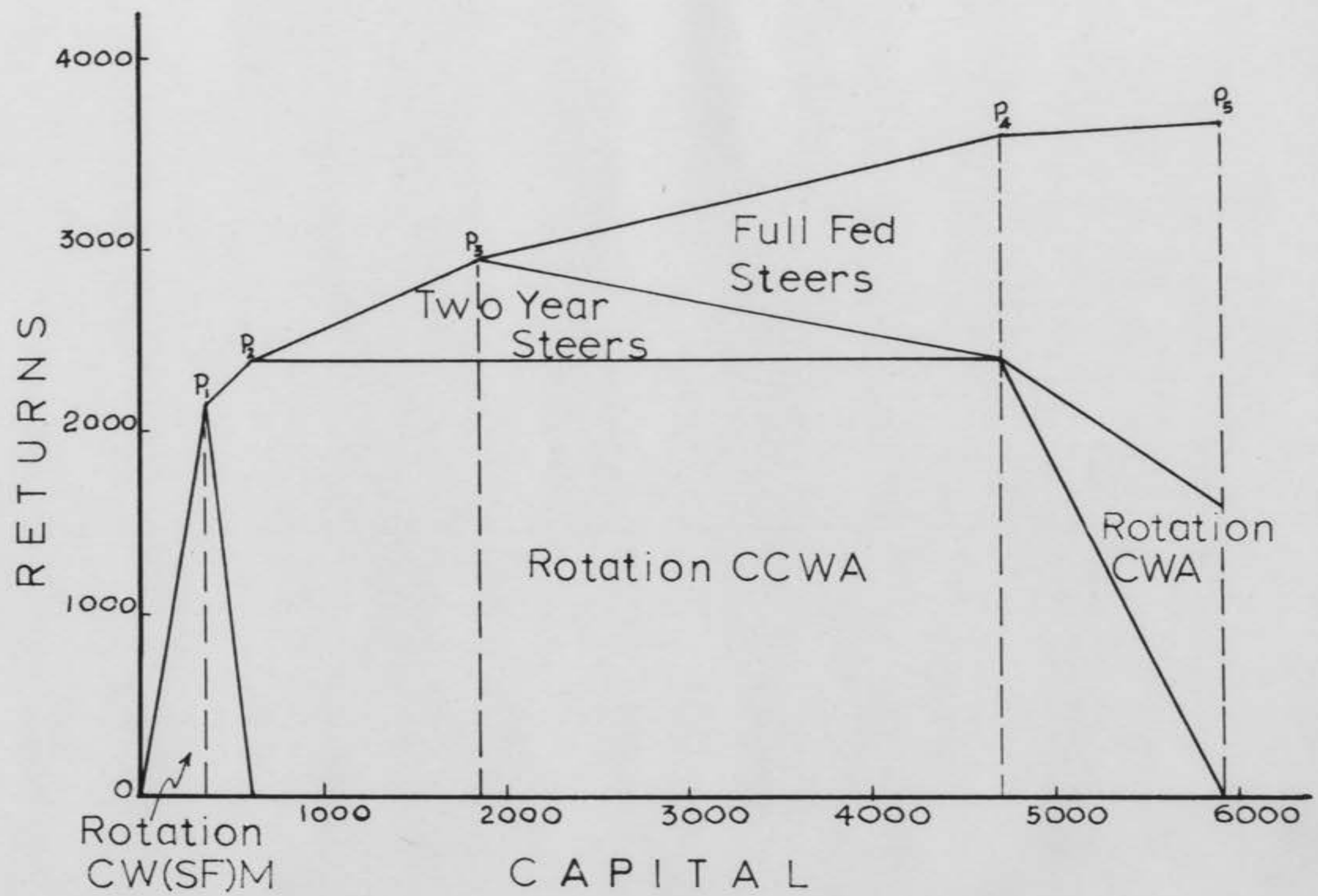

Figure 10. Source of returns, Situation 5

following differences can be noted:

a. The rotation systems in the programmed plans have a greater proportion of corn, wheat and forage crops.

b. With no hog enterprises permitted to compete, the programmed plans include two-year-old steers instead of a combination of beef raising and hog production.

c. Returns to labor, capital and management for the programmed plan are $2600, $85 higher than under the prevailing plan. Such a small increase in returns would not justify the replacement of the present system of operation by the optimum plan obtained along with the restrictions set for this situation.

Situation 6: Optimum Plans for 245-Acre Farm, Including 11 Rotations, Beef Cattle Enterprises, But Excluding Hog, Poultry and Labor Hiring Activities

Situation 6 differs from Situation 5 in the size of farm and in the number and characteristics of the enterprises included. Eleven rotations and 5 beef cattle enterprises are considered as alternatives in Situation 6.

Plans 1 and 2

Plans 1 and 2 in this situation with $700 and $759 of capital follow the same pattern as in Situation 4.

Plan 3

In this plan no livestock enterprise is permitted because the amount of capital, $1157, is still more profitably allocated to crops.

The farming system changes from 245 acres of rotation CCW(SP)M to 245 acres of rotation CCWA which results in more corn and hay than in Plans 1 and 2.

Plan 4

The optimum plan with $3550 capital includes the same rotation as before and yields 5830 bushels of corn and 159.2 tons of hay. However, the amount of capital is now sufficient to allow the purchase and feeding of 37 two-year-old steers. This beef enterprise consumes all the hay produced, and all corn produced can be sold.

This crop-livestock combination brings to the operator $5714 as returns to labor, capital and management. Hay becomes restrictive along with capital and land. Approximately 24% of the annual labor supply is used.

Plan 5

When increasing the capital level from $3550 to $9047, the rotation system and crop output remain unchanged, but the larger amount of capital permits the purchase of 104 steers which are full-fed with part of the corn and all of the hay produced.

Returns are $6949 for this plan, $1235 higher than for Plan 4. On the other hand, the utilization of labor is only slightly increased from 1182 hours to 1233 hours per year.

Plan 6

At the highest level of capital, $17,930, rotation CCWA is replaced by rotation CCOAAA, on all 245 acres, which produces much more forage and much less corn than rotation CCWA in the previous plan. The production of hay is increased to 347 tons. Hence, 227 steers can be full fed, still leaving 1370 bushels of corn to be sold.

Returns for this plan are $8001. Labor is still underemployed since no more than 28% of the total labor supply is used at the highest level of capital use.

Plans 1 to 6 are presented in detail in Table 22.

Effects of different levels of capital with farm size and labor supply constant

In Situation 6, farming alternatives are reduced to one rotation system and one beef cattle enterprise.

In the first three plans with limited capital, returns are maximized with crops only. Larger amounts of capital permit the addition of steer feeding programs.

In the plan involving the most capital, $17,930, rotation CCOAAA replaces rotation CCWA and a greater amount of forage is produced. Consequently, more forage consuming livestock can be raised.

However, if Plan 6 were to be put into operation, the marginal productivity of capital would be only 11.8%, or 11.8 cents for each dollar invested. If the interest rate on borrowed capital is 12%, it would not be economical to operate beyond the capital level indicated in Plan 5, i.e., $9047.

Table 22. Situation 6: optimum plans for six levels of capital, 245-acre farm

Item	Plan 1	2	3	4	5	6
Level of capital ($)	700	759	1157	3550	9047	17930
Crop rotations (acre)						
CWA						
CCWA			245	245	245	
CW(SF)M	245					
COM						
COMMM						
CCCCWA						
CCW(SF)M		245				
CCCW(SF)M						
CCCOM						
CCOAAA						245
CCCWA						
Beef cattle (head)						
Beef cow calves sold						
Beef cow calves fed						
Yearling steers						
Two-year-old steers				37		
Full fed steers					104	227
Corn eq. produced (bu.)	2940	4210	5880	5880	5880	4770
Hay eq. produced (ton)	73.5	63.7	159.2	159.2	159.2	347.0

Table 22 (Continued)

Item	Plan 1	2	3	4	5	6
Unused manhours (monthly)						
January	474	471	378	371	378	287
February	490	490	474	462	474	433
March	401	414	464	451	445	396
April	337	339	235	229	225	154
May	260	202	151	150	139	203
June	367	371	367	359	338	226
July	390	390	390	382	361	326
August	283	249	252	244	222	280
September	313	299	211	203	200	241
October	326	321	326	323	326	346
November	352	335	228	221	228	104
December	421	434	421	417	421	490
Used manhours (annual)	586	685	1103	1182	1233	1414
Corn eq. sold (bu.)	2940	4210	5880	5860	4320	1370
Unused hay eq. (ton)	73.5	63.7	159.2	0	0	0
Return to labor, capital and management ($)	4140	4351	4608	5714	6949	8001
Limiting resources	Cap. Land	Cap. Land	Cap. Land	Cap. Land Hay	Cap. Land Hay	Cap. Land Hay

Throughout Plans 1 to 6, labor is still underemployed; only 28% of the total labor supply is used in the plan that yields the highest returns. Operator labor alone would be sufficient to fulfill all labor requirements for the year.

Situation 6 is graphically represented in Figure 11. Another graphic representation (Figure 12) shows the relative contribution of activities to returns at different capital levels.

Table 23. Situation 6: marginal productivity of capital

Plan no.	Level of capital	Returns	Marginal productivity
1	700	4,140	5.92
2	759	4,351	3.58
3	1,157	4,608	0.65
4	3,550	5,714	0.46
5	9,047	6,949	0.22
6	17,930	8,001	0.118

<u>Comparison of program plans to systems typically followed in the area</u>

In comparing plans typical of the area with the optimum plan obtained from programming for similar capital levels the following differences can be noted:

a. The typical rotation system in the plan followed by the

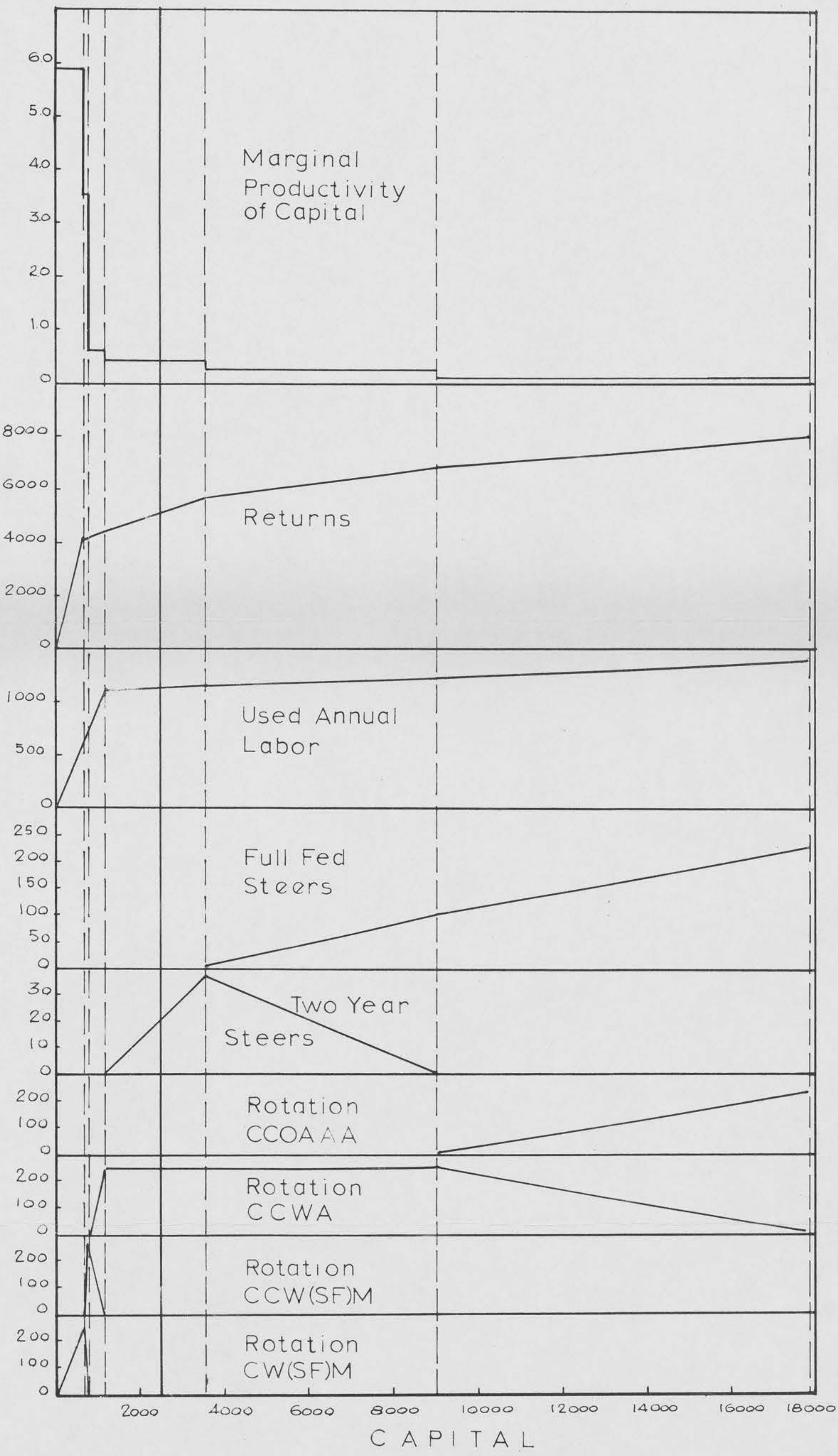

Figure 11. Graphic representation of Situation 6

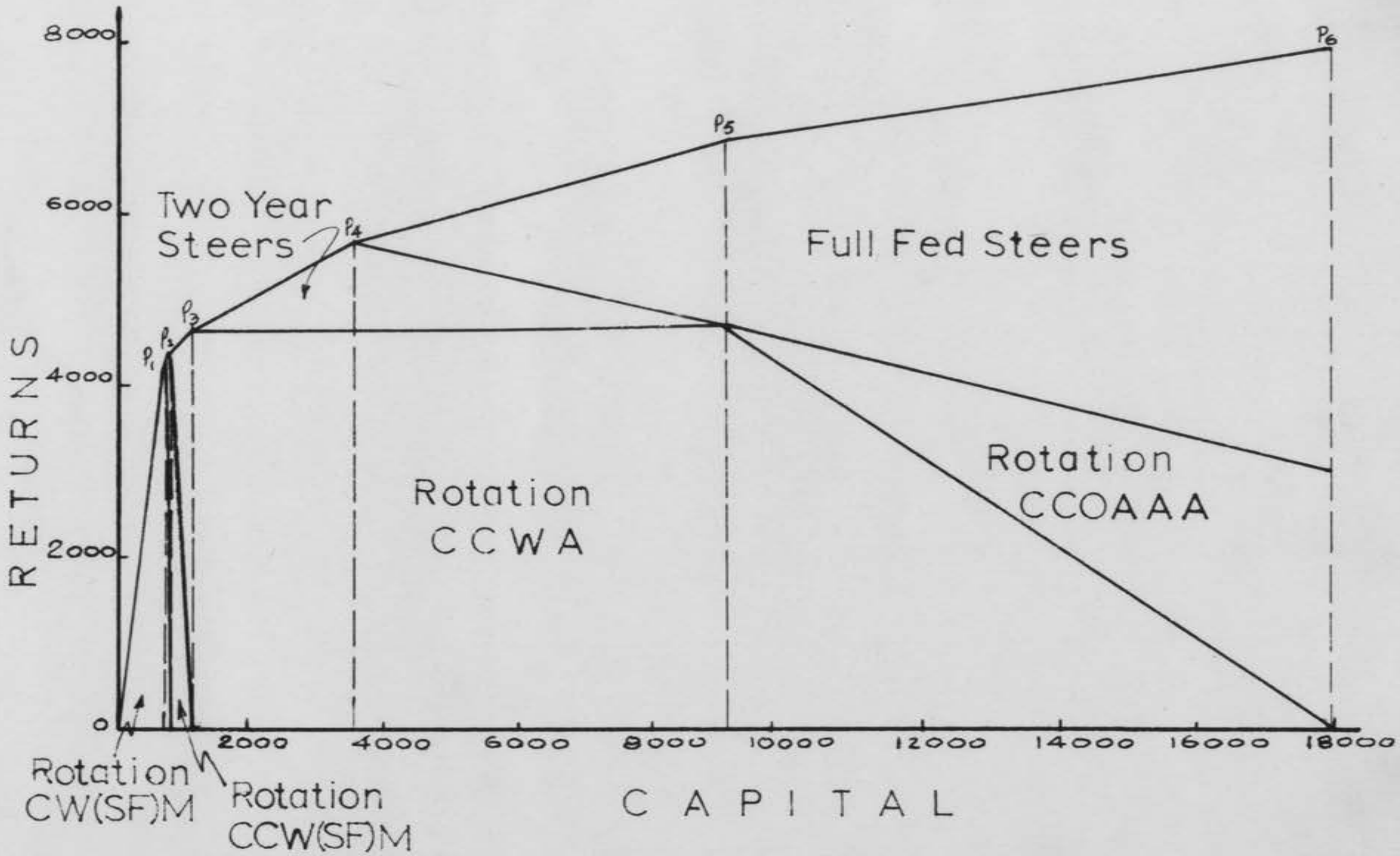

Figure 12. Source of returns, Situation 6

farmer, CW(SF)M is replaced by rotation CCWA in the optimum plan.

b. With no hog enterprises permitted to compete, the programmed plan includes two-year-old steers instead of the typical combination of beef raising and hog production.

c. Because of these changes, returns for the programmed plan increase from $4801 in the system actually used by the farmer to $5200.

Effect of different levels of capital and farm size upon enterprise combination and returns

At lowest levels of capital, Plans 1 and 2 in both Situations 5 and 6, crop rotations are the most profitable activities.

Plan 3 in Situation 5 (128-acre farm) uses more capital and results in lower returns than Plan 3 in Situation 6 (245-acre farm). There is substitution of capital for land. At the level of capital set for Plan 3, profits are maximized by farming 245 acres of rotation CCWA without using a livestock enterprise. On the 128-acre farm however, 19 units of livestock, which requires more capital, must be introduced to maximize profits. The operator of the 245-acre farm, with only crop activities, has a lower capital requirement than the farmer operating 128 acres, but obtains greater returns.

In Plan 4 of both Situations 5 and 6, almost the same pattern emerges, with the exception that a livestock enterprise enters the plan on the 245-acre farm.

Finally, a pattern common in Situations 1 through 4 is also evident for Situations 5 and 6. On the small farm, the supply of hay or corn is not large enough to justify the investment of greater amounts of capital in buying livestock beyond certain limits. On the larger farm, because of the greater production of hay and corn, more capital can be profitably used. In Situation 5 (128-acre farm) capital can be used only to the $5898 level. In Situation 6 (245-acre farm) capital can be used to the $17,930 level before hay becomes limiting.

With hog enterprises excluded from the range of activities considered, labor is no longer a limiting factor in any of the plans in both Situations 5 and 6.

Situation 7: Optimum Plan Considering Non-Limiting Land, Non-Limiting Capital, 11 Crop Rotations and 9 Livestock Enterprises

At this point an attempt was made to answer the following questions by means of the same input-output coefficients utilized in the previous analyses:

a. What farm size would be needed to optimize the utilization of the present annual labor supply of 5000 hours for the 245-acre farm?

b. What capital would be needed for this optimum plan?

c. What enterprises would be included in this plan?

d. How much profit could be obtained from such a plan?

In this phase of the study land and capital restrictions were completely removed. It was assumed that any amount of amount of land and capital needed to maximize profits with the current supply of labor could be obtained.*

Under these conditions the optimum plan obtained with the programming procedure would include the resources and enterprise combinations given in Table 24. Eight hundred seventy-eight acres would be operated by the family labor supply. Returns to this plan would be $17,720.

May labor and hay are resources limiting plans that make more intensive use of the remaining labor. Obviously, the plan could be expanded by hiring May labor and buying hay if the marginal productivity of these resources were greater or equal to their marginal costs.

Another situation (Situation 8) was computed, in which the same crops and livestock enterprises used in Situation 6 were included. But since the final plan turns out to be almost identical to that described above, this situation is not presented.

It is significant that steers displace hog enterprises when large amounts of land and capital are used. This is what many farmers of the area having large amounts of land and capital are doing after many years of trial and error.

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*To simplify the linear programming procedure in obtaining answers to the above questions, practically unlimited amount of land and capital was assumed, say 10,000 acres and 1 million dollars. In this manner labor will be a positive limitation before land and capital themselves become positive restrictions.

Table 24. Optimum plan with non-limiting land, non-limiting capital, and with labor supply held equivalent to 245-acre farm size

Land	878 acres
Capital	37,900 dollars
Crop rotation	878 acres of COMMM
Livestock enterprise	484 full fed steers
Corn equivalent produced	11,414 bushels
Corn equivalent sold	4,182 bushels
Hay equivalent produced	737.5 tons
Hay equivalent unused	0
Manhours used	1,790
Unused manhours (monthly)	
January	367
February	280
March	191
April	321
May	0
June	255
July	255
August	57
September	232
October	318
November	102
December	390
Return to labor, capital and management	17,720 dollars

SUMMARY

The purpose of this study was to present and compare plans which will maximize profits for 128- and 245-acre farms in Pergamino County, Province of Buenos Aires, Argentina. In addition, an attempt was made to determine at what level of capital the labor supply would limit production and how much labor would remain unused after other resources had limited the production process. A final objective was to determine the farm size (amount of land) needed to make full use of the existing labor supply.

Most of the situations analyzed in this study assumed variable levels of capital, freely allocable among activities. The supply of labor was generally restricted to the operator's labor plus additional labor of other members of the family. Hired labor was permitted in two planning situations.

Farming programs presently followed on farms in the area were compared with optimum plans derived by linear programming. In computing the optimum plans, allowance was made for the inclusion of a wider range of crop and livestock alternatives than are typically considered by farm operators in the region.

The results obtained from the analysis lead to the following conclusions:

1. At low levels of capital, optimum plans included only

crop activities, since at this point funds are most profitable invested in crop rotations.

2. Returns from the programmed plans were higher than from existing programs, assuming similar capital levels, especially for the 245-acre farm. Therefore, given the present capital limitations, to maximize profits the present farming system should be altered in most of the situations analyzed. The rotation systems indicated by optimum programming solutions contained larger acreages of corn than is grown in the area. When a laying flock was included in the range of activities considered, it replaced the existing beef cattle-hog combination. When laying hens were excluded as alternatives, the beef raising and the one litter hog system typical of the area were replaced in the optimum plan by a two litter hog system. When neither hogs nor laying hens were included as possible alternatives, the widely used beef cow-hog combination was replaced by feeding two-year-old steers.
3. Returns may be increased by borrowing capital. In subsequent plans, as the amount of operating capital used in the production process increased, additional funds were profitably invested in a laying flock, a combination feeder cattle-hog program or in a feeder cattle enterprise.

4. The marginal productivity of capital was higher when hog enterprises were included along with feeder cattle than where cattle were the sole livestock activity. For most of the plans computed, returns to each dollar borrowed and invested were greater than the annual interest rate for borrowed capital of 12 percent. Therefore, if risks associated with heavy borrowing are not considered, the farmer could rationally borrow capital to increase the scale of operation.
5. The family labor supply on farms of the two sizes analyzed in this study could not be fully utilized by crop and livestock enterprises, except where a poultry enterprise was added. In most cases studied, one of the members of the family could leave the farm and accept off-farm employment for 7 or 8 months of the year without reducing the size of operation or changing the farming program significantly. Hiring labor at the current wage would be profitable for plans including intensive enterprises requiring more labor than provided by the operator and his family.
6. In comparing the 128-acre and the 245-acre farms, the results showed that the larger farm allowed the profitable use of much greater amount of operating capital. On the smaller farm, resources other than capital were limiting before amounts of capital

comparable to those used on the 245-acre farm could be applied.

7. With land and capital non-limiting and a fixed labor supply (Situation 7) the solution showed that the optimum plan included 878 acres of a rotation with a large amount of roughage, a cattle feeding enterprise, but no hog enterprise.

Finally, it should be remarked that optimum plans suggested are relevant only for farms with characteristics similar to those analyzed in this study. The application of results obtained to farms with different resource characteristics could lead to wide errors of inference.

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APPENDIX

Table 25. Estimated production requirements and income for beef cow herd; calves born in early September; not creep fed; winter ration of alfalfa hay and pasture; selling good choice feeder calves, early April

Livestock investment

Basic stock: brood cow (lbs)	1100
Replacement and death loss: 18% (lbs)	198
Total (lbs)	1298
Price per cwt ($)	6.70
Basic stock including replacement and death loss ($)	86.967

Bull purchase
(1 bull for 25 cows)

a. Value per head ($)	244.00
b. Sale value after 3 years ($)	170.00
c. Average value for 25 cows ($)	207.00
d. Average value for 1 cow ($)	8.28
e. Depreciation in 3 years for 25 cows (a-b)($)	74.00
f. In 1 year for 1 cow ($) $\frac{e}{25 \times 3}$	0.987

Summary investment

Basic stock including replacement and death loss ($)	86.967
Bull purchase (d)($)	8.280
Total	95.247

Output
(90% calf crop; 5% death loss; 17% saved for replacement)

Item	Rate	Weight	Price per cwt	Total value
Steer calf	.43	450	8.575	16.593
Heifer calf	.25	430	8.392	9.021
Cull cow	.17	1100	5.726	10.708
Total receipts				36.322

Table 25 (Continued)

Input			
Item	Rate	Price per unit	Total value
Pasture (AUM)	11.5	-----	-----
Hay (alfalfa 6 lbs/day 90 days)[a] (ton)	0.27	1.148	0.310
Minerals (lbs)	20	0.03	0.600
Vet and med ($)	-----	-----	0.300
Bull depreciation ($)	-----	-----	0.987
Miscellaneous (15% of total receipts)($)	-----	-----	0.545
Total enterprise cost			2.742
Income over cost			33.580
Capital coefficient			97.989

[a]All hay is raised on farm. Therefore price of hay is equal to harvesting variable cost.

Table 26. Estimated production requirements and income for beef cow calves creep fed; calves born in early May; winter ration of corn, hay and pasture; selling good-choice feeder steers, late February

Livestock investment

Basic stock: brood cow (lbs)	1100
Replacement and death loss: 18% (lbs)	198
Total (lbs)	1298
Price per cwt ($)	6.70
Basic stock including replacement and death loss ($)	86.967

Bull purchase
(1 bull for 25 cows)

a. Value per head ($)	244.00
b. Sale value after 3 years ($)	170.00
c. Average value for 25 cows ($)	207.00
d. Average value for 1 cow ($)	8.28
e. Depreciation in 3 years for 25 cows (a-b)($)	74.00
f. Depreciation in 1 year for 1 cow $\frac{a}{25x3}$ ($)	0.987

Summary investment

Basic stock including replacement and death loss ($)	86.967
Bull purchase ($)	8.280
Total	95.247

Output
(90% calf crop; 5% death loss; 17% saved for replacement)

Item	Rate	Weight (lbs)	Price per cwt ($)	Total value ($)
Steer calf	.43	560	9.650	23.237
Heifer calf	.25	530	9.650	12.786
Cull cow	.17	1100	5.726	10.708
Total receipts				46.731

Table 26 (Continued)

Item	Rate	Price per unit ($)	Total value ($)
	Input		
Pasture (AUM)	13[a]	----	----
Corn equivalent (bu.)	12.5	0.70	8.75
Hay (ton)	0.27	1.148	0.31
Minerals (lbs)	20	0.03	0.60
Vet and med ($)	----	----	0.30
Bull depreciation ($)	----	----	0.99
Miscellaneous (15% of total receipts ($)			0.70
Total enterprise cost			11.65
Income over cost			35.08
Capital coefficient			106.90

[a]Includes 1.5 AUM for calf.

Table 27. Estimated production requirements and income for producing good feeder cattle; bought early October; grazing during summer; sold early February

Item	Amount	Price	Value
	Output		
Feeder (cwt)	7.25	$8.104	$58.75
Less 1% death loss			58.17
	Input		
Calf (cwt)	5.00	8.575	42.87
Pasture (AUM)	3.0	-----	-----
Vet. and med. ($)	0.12		0.12
Minerals (lbs)	8.00	0.03	0.26
Miscellaneous 1% gross income			0.58
Total enterprise cost			43.81
Income over cost			14.36
Capital coefficient			43.81

Table 28. Estimated production requirements and income for producing two-year-old feeder or slaughter cattle; bought early February; year round pasture; winter supplement; sold off grass early February

Item	Amount	Price	Value
	Output		
Feeder or slaughter (cwt)	1.150	8.392	96.51
Less 1% death loss			95.55
	Input		
Stocker (cwt)	7.25	8.104	58.75
Pasture (AUM)	12	-----	-----
Supplement (cwt)	3.75	1.30	4.87
Hay (ton)	.025	1.148	0.29
Vet and med	----	-----	0.12
Minerals (lbs)	16	0.03	0.48
Miscellaneous 1% gross income			0.84
Total enterprise cost			65.35
Income over cost			30.20
Capital coefficient			65.35

Table 29. Estimated production requirements and income for producing choice feeder cattle on pasture for 120 days and full fed in dry lot for 75 days

Item	Amount	Price	Value
	Output		
Feeder (cwt)	11.83	8.392	99.28
Less 1% death loss			98.29
	Input		
Yearling purchase cost (cwt)	7.78	8.104	63.05
Pasture (AUM)	4	-----	
Corn (bu.)	15	0.70	10.50
Hay (ton)	0.08	1.148	0.09
Supplement (cwt)	0.45	1.30	0.58
Vet and med			0.12
Minerals (lbs)	16	0.03	0.48
Miscellaneous 1% gross income			0.98
Total enterprise cost			75.80
Income over cost			22.49
Capital coefficient			75.80

Table 30. Estimated production requirements and income for producing hogs in one spring litter, one fall litter and two litter systems

	1:0	1:1
Basic stock		
Sow: weight per head (lbs)	225	225
Number	1	1
Price per cwt ($)	12.50	12.50
Total purchase	28.12	28.12
Output		
a. From hogs		
Pig weaned per unit	7	14.6
Death loss: 4%	0.28	0.58
Replacement gilt	1	1
No. of hogs marketed per unit	5.72	13.02
Selling weight per hog (lbs)	225	215
Total hog sold (lbs)	1287	2799
Selling price per cwt ($)	11.862	11.862
Output from hogs ($)	152.66	330.07
b. From cull sow		
Cull sow sold	1	1
Selling weight (lbs)	350	400
Selling price per cwt ($)	9.201	9.201
Output from cull sow ($)	32.20	36.80
Total output	184.86	366.87
Input		
Feed		
Corn: volume (bu.)	112	203
weight (lbs)	6272	11368
Protein (lbs)	648	1350
Total concentrate (lbs)	6920	12718
Protein corn ratio	9.7	8.4
Pasture (ton)	1	1.4
Total output (lbs)	1637	3199
Concentrates per lb output	4.227	3.98

Table 30 (Continued)

	1:0	1:1
Input (Continued)		
Cash expenses		
Corn @ $0.70 per bushel	78.40	142.10
Protein @ $2.60 per cwt	16.85	35.10
Breeding charge	1.50	3.00
Vet and medical	6.00	12.00
Miscellaneous (1.5% of gross income)	2.77	5.86
Shelling	2.18	3.98
Total	107.70	202.04
Summary		
Output	184.86	366.87
Cash expenses	107.70	202.04
Net revenue or income over cost	77.16	164.83
Investment	28.12	28.12
Cash expenses	107.70	202.04
Capital coefficient	135.82	230.16

Table 31. Estimated production requirements and income for producing feeder pigs (10 units)

Item	Amount	Weight	Price	Value ($)
		Output		
Feeder pigs (head)	10	220	11.862	260.96
Less 3% death loss				253.13
		Input		
Pig (head)	10	40	8.00	32.00
Corn eq. (bu.)	112	--	0.70	78.40
Hay eq. (ton)	0.3	--	1.148	0.36
Protein, mineral (cwt)	8	--	2.60	20.80
Vet. and med.				14.00
Miscellaneous (2.0% of all expenses)				3.87
Total enterprise cost				149.41
Income over cost				103.72
Capital coefficient				149.41

Table 32. Estimated production requirements and income for producing commercial laying flock (10 hens)

Item	Amount	Weight	Price	Value ($)
		Output		
Cull pullets (head)	1	4	0.166	0.664
Cull hens (head)	8.5	4.5	0.166	6.349
Eggs (dozen)	180	----	0.250	45.000
Total output				52.013
		Input		
Sexed chicks (head)	12		0.340	4.092
Corn eq. (bu.)	11.2		0.70	7.840
Pasture (ton)	0.1		1.148	0.115
Protein salt minerals (cwt)	5.8		2.60	15.100
Vet. and medical				0.365
Miscellaneous (2% of all expenses)				0.550
Total enterprise cost				28.057
Income over cost				23.956
Capital coefficient				28.057

Table 33. Estimated per acre requirements, variable costs and net revenue for corn enterprise

Item	Price or cost per unit	Quantity	Value or cost
	Input		
Growing			
Seed (bu.)	3.08	0.255	0.785
Insecticide (gal.)	5.10	0.080	0.408
Tractor (hr.)	0.709	2.516	1.783
Machinery:			
Plow (hr.)	0.211	0.760	0.160
Disk (hr.)	0.246	0.368	0.090
Harrow (2)(hr.)	0.007	0.511	0.003
Plant (hr.)	0.158	0.292	0.046
Cultivate (2)(hr.)	0.158	0.455	0.071
Spray (hr.)	0.360	0.130	0.047
Specified preharvest costs			3.393
Harvesting			
Tractor (hr.)	0.709	0.600	0.425
Pick (hr.)	0.650	1.070	0.695
Total specified costs			4.513
Capital coefficient			4.513

Table 34. Estimated per acre requirements, variable costs and net revenue for wheat enterprise

Item	Price or cost per unit	Quantity	Value or cost
	Input		
Growing			
Seed (bu.)	0.99	1.345	1.331
Insecticide (gal.)	5.100	0.080	0.408
Tractor (hr.)	0.803	1.416	1.137
Machinery:			
Plow (hr.)	0.360	0.625	0.225
Disk (hr.)	0.193	0.292	0.056
Harrow (hr.)	0.014	0.162	0.002
Drill (hr.)	0.208	0.212	0.044
Spray (hr.)	0.098	0.125	0.012
Specified preharvest costs			3.215
Harvesting			
Combine (hr.)	0.660	0.450	0.297
Hauling (hr.)	0.803	0.680	0.546
Total specified costs			4.058
Capital coefficient			4.058

Table 35. Estimated per acre requirements, variable costs and net revenue for oats enterprise

Item	Price or cost per unit	Quantity	Value or cost
	Input		
Growing			
Seed (bu.)	0.44	2.5	1.100
Tractor (hr.)	0.803	1.129	0.906
Machinery:			
Plow (hr.)	0.360	0.625	0.225
Disk (hr.)	0.193	0.292	0.056
Drill (hr.)	0.208	0.212	0.044
Specified preharvest costs			2.331
Harvesting			
Combine (hr.)	0.660	0.450	0.297
Hauling (hr.)	0.803	0.680	0.546
Total specified costs			3.174
Capital coefficient			3.174

Table 36. Estimated per acre requirements, variable costs and net revenue for sunflower enterprise

Item	Price or cost per unit	Quantity	Value or cost
	Input		
Growing			
Seed (bu.)	1.78	0.385	0.685
Tractor (hr.)	0.803	1.416	1.137
Machinery:			
Plow (hr.)	0.360	0.625	0.225
Disk (hr.)	0.193	0.292	0.056
Harrow (hr.)	0.014	0.162	0.002
Drill (hr.)	0.208	0.212	0.044
Spray (hr.)	0.098	0.130	0.012
Specified preharvest costs			2.161
Harvesting			
Combine (hr.)	0.660	0.450	0.297
Hauling (hr.)	0.803	0.500	0.401
Total specified costs			2.859
Capital coefficient			2.859

Table 37. Estimated per acre requirements, variable costs and net revenue for alfalfa enterprise

Item	Price or cost per unit	Quantity	Value or cost
	Input		
Growing			
Seed (lb.)	0.32	13	4.160
Tractor (hr.)	0.709	1.871	1.327
Machinery			
Plow (hr.)	0.128	0.91	0.116
Disk (hr.)	0.286	0.37	0.106
Harrow (hr.)	0.087	0.21	0.018
Drill (hr.)	0.336	0.27	0.091
Specified preharvest costs			5.818
Annual preharvest costs (left down five years)			1.164
Harvesting			
Mower[a] (hr.)	0.300	1.945	0.583
Rake (hr.)	0.248	1.410	0.350
Baler (hr.)	0.340	4.660	1.584
Hauling (hr.)	0.803	0.44	0.353
Total harvesting cost			2.870
Total specified costs per year			4.034
Variable harvesting cost per ton			1.148
Capital coefficient			4.034

[a]Time of operation is multiplied by 4 because alfalfa is cut 4 times per year.

Table 38. Variable costs, gross and net revenue for different crop enterprises and different yields

Yield (bu.)	Gross revenue	Variable costs	Net revenue
	Corn		
52	36.40	4.51	31.89
50	35.00	4.51	30.49
48	33.60	4.51	29.09
46	32.20	4.51	27.67
43	30.10	4.51	25.59
40	28.00	4.51	23.49
38	26.60	4.51	22.09
34	23.80	4.51	19.29
28	19.60	4.51	15.09
	Wheat		
25.5	22.00	4.06	17.94
24.5	21.14	4.06	17.08
23.5	20.28	4.06	16.22
22.5	19.42	4.06	15.36
	Oats		
30	11.86	3.17	8.69
28	10.54	3.17	7.37
	Sunflower		
16	24.29	2.86	21.43
15	22.77	2.86	19.91

Table 39. Farming operations by months and crops, Pergamino area, Province of Buenos Aires, Argentina

Month	Corn	Wheat	Oats	Sun-flower	Alfalfa
January	Spray	-----	-----	Spray	3rd cut
February	-----	-----	Plow	-----	Plow Disk
March	-----	-----	Disk Drill	Combine	Harrow Drill
April	-----	Plow	-----	-----	4th cut
May	Pick	Disk	-----	-----	-----
June	-----	Harrow Drill	Grazing	-----	-----
July	-----	-----	Grazing	-----	-----
August	Plow Disk	-----	-----	Plow	-----
September	1st harrow 2nd harrow	-----	-----	Disk Harrow	1st cut
October	Plant	Spray	-----	Plant	-----
November	1st cultiv. 2nd cultiv.	-----	Combine	-----	2nd cut
December	-----	Combine	-----	-----	-----

ACKNOWLEDGMENT

The author is indebted to Professor Raymond E. Bemske for his stimulus and his many valuable suggestions and helpful criticism. Thanks to him the composition chores of this study have been substantially lightened. The author also benefited from discussion with Professor Herbert B. Howell concerning the local conditions of the area studied.